Synthesis & Property Evaluation of metal alloy & Hybrid Composites-A Review

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Abstract

Metal Alloy Composites alloys have been in use for tribological applications like internal combustion engines, pistons, liners, clutches, pulleys, rockers, and pivots. However, in all these applications there is a requirement of significant enhancements in-service loads and wear resistance, thus forcing the material researchers to develop aluminum-based composites. The conventional aluminum-based composites possess only one type of reinforcement. Addition of hard dispersions such as silicon carbide, alumina, titanium carbide, flash leads to improved hardness, strength, and wear resistance of the composites. However, these composites possessing hard reinforcement do pose several problems during the machining of metal matrix composites. Further, the addition of ceramic reinforcements will result in deterioration of both thermal and electrical conductivity of aluminum alloys leading to limited applications.

Keywords:-Metal alloy composite, XRD, EDAX, Thermal & Electrical Conductivity.

I. Introduction

However meager information is available as regards the development of aluminum-based hybrid metal matrix composites and the effect of heat-treatment on these hybrid composites. Hence the present investigation is aimed at developing aluminum-silicon-based hybrid metal matrix composites consisting of electroless copper-coated graphite particulates and short carbon fiber reinforcement and to characterize their mechanical and tribological properties before and after heat-treatment.

Aluminum-Silicon-graphite, Aluminum-Silicon-carbon fiber and Aluminum-Silicon-graphite-carbon fiber, hybrid composites with different vol% of the reinforcement were prepared by vortex method using commercially available scrap pistons. The effect of reinforcement of copper-coated graphite particulates and carbon short fibers on the microstructure, micro hardness, tensile strength, Coefficient of friction, adhesive wear and abrasive wear resistance of the matrix alloy and the developed hybrid composites were studied. Corrosion studies (Polarization studies) on the matrix alloy and the developed composites were also studied. Friction and Wear tests of cast aluminum-silicon alloy and the developed hybrid composites were conducted using standard computerized Pin-on-Disc wear test rig as per ASTM G99-95 before and after heat-treatment both at room and elevated temperatures. Abrasive wear tests on both matrix alloy and the developed hybrid composites were conducted using abrasive wear test rig as per ASTM G65. SEM and Energy dispersive X-ray analyses (EDAX) have been carried out on the worn surfaces of cast aluminum-silicon alloy and the developed hybrid composites. Polarization studies in 3.5%NaCl using potentiostat-galvanostat computerized electrochemical interface corrosion.

1.1 Mechanical Properties of Metal Matrix Composites

Many Properties of Metal Matrix Composite material is the resistance of metal to plastic deformation, usually by indentation. However, the term may also be referred to as resistance to scratching, abrasion, or cutting [J.I. Song and K.S. Han 1977]. In general, the addition of hard reinforcement in the matrix alloy results in the improved hardness of the composites. However, the presence of soft reinforcement in the matrix alloy reduces the hardness of the obtained composites. The type and extent of incorporation of the reinforcement have a profound influence on the hardness of the composite [M. Gupta and M.K. Surappa 1995]. Aiguo Wang and H.J. Rack (1991) have reported that an increase in SiC vol% increases the hardness of 2124Al. The hardness of the composites depends on the nature of reinforcement present and also on the quantity of the reinforcement. An improvement in the hardness of Al-Si-alloy due to heat-treatment has been reported by M.M. Haque, M.A. Maleque (1998). S. Sawla and S. Das (2004) have reported that there is an improvement in hardness by 22% for LM-13 alloy and LM-13-15wt%SiCp due to reinforcement and improvement by 33% due to combined effect of reinforcement and heat-treatment. Anwar Khan et al (2002) have studied the heat treatment effect on the hardness of Al6061-10wt% SiC composites. An increase in revolutionising time increases the hardness of the composites. Sahin et al (1999) have evaluated the hardness for the different volume fraction of SiC with Al-Si alloy matrix. The hardness of the MMCs increased more or less linearly with the volume fraction of SiC particles in the alloy matrix. A higher hardness was also associated with lower porosity. It is reported that with the increased contents of TiO2 in the Al6061 matrix, the probable formation of Al-Ti intermetallic precipitate and alumina significantly contributes to the enhancement of the hardness of composites [C.S. Ramesh et al (2005)]. J. B. Yang et al (2004) have reported that an increase in the volume fraction of copper-coated graphite increases the hardness of A356Al alloy. It is reported by Hyrettin Ahlatci et al (2004) that there is an increase in hardness with an increase of Si in Al-Si/SiC composites which is attributed to precipitation of eutectic silicon since solid solubility of silicon in the aluminium matrix is 1.65% at room temperature.

1.2 Heat-treatment of Aluminum-based composites

S. Das (2004) have investigated the effect of heat treatment on the abrasive wear of aluminum alloy and aluminum particle composites and found that heat-treated composites possessed high wear resistance compared to un-heat treated composites. M.M. Haque and M.A. Maleque (1998) investigated the effect of heat- treatment on the structure and properties of aluminum-silicon piston alloy and observed that due to heat-treatment there was an increase in strength at the expense of ductility and refinement in the microstructure. H. Akbulut et al (1998) studied the effect of standard T6 heat treatment on dry wear and friction properties of short fiber reinforced Al-Si (LM-13) alloy metal matrix composites and found that the wear resistance of the composites increased due to heat-treatment.

1.3 Corrosion

Corrosion is defined as the destruction or deterioration of a material which begins at the surface of metals due to chemical and electrochemical attack [Mars G. Fontana 1987]. Corrosion is the term generally used to describe the chemical “wasting” which occurs when a metal or alloy reacts with the environment within which it is in contact [Robert Akid 2004].

1.4 Factors affecting the rate of corrosion:

(a) Environment

The rate of corrosion reaction will be determined by the nature and concentration of the reacting species of the environment. These include water content (humidity), the presence of chloride, oxides of sulfur. Carbon in the form of CO2 influences the rate of corrosion by causing a drop in pH of aqueous phases on the surfaces of the metals, which acts as cathodic sites. When the environment is aqueous, the corrosion rate is influenced by solution conductivity, acidity, dissolved gases, solids, and temperature. In general, natural water varies in their compositions which are dependent on nature. Typically natural waters vary from very soft (low CaCo3) to very hard. Seawater environments are naturally more aggressive than natural waters due to the presence of a high concentration of salts such as chloride. Seawater is a complex electrolyte whose composition varies from place to place.

(b) Concentration

In general increasing concentration of reactive species leads to an increase in the corrosion rate, for example, increasing the hydrogen ion concentration of a solution, ie decreasing the pH, causes an increase in corrosion rate. However, a decrease in corrosion rate only is observed where solution chemistry leads to the formation of the passive film on the surface of the metals [C.S. Ramesh et al 1992].

(c) Temperature

An increase in temperature also tends to increase the corrosion rate. For example, an increase in temperature of 100 C will tend to double the corrosion rate. Such effects are however not universal as increasing the temperature of a solution affects the concentration of gases dissolved in solution, notably oxygen. Increased corrosion rates are the results of increased mass transport, which for oxygen reduction controlled reactions occur at about 800C.

(d) Solution Velocity

Solution velocity affects the corrosion rate of metals by affecting the rate of mass transport of species to and from the reaction sites and also by affecting the stability of the passive films. In addition to this, increased flow rates affect whether not corrosion products remain at the anode/cathode sites, thereby affecting the ability of the subsequent electron transfer processes.

2. Literature review

Amanda McKiea, Jamiet al [1] The relationship between microstructure and mechanical properties for a wide range of composite materials based on polycrystalline cubic boron nitride and aluminum as a binder phase (PcBN–Al) has been examined. The cBN–Al composites were made using high-pressure, high-temperature (HPHT) sintering methods, yielding materials with grain sizes of cBN between 2 and 20 µm and an initial amount of Al binder between 15 and 25 vol.%. Hardness ranged between 15 and 40 GPa, while fracture toughness and strength were between 6.4–8.0 MPa m1/2 and 355–454 MPa, respectively. Fractography was employed to investigate the large scatter in fracture strengths and correlate fracture strength with fracture toughness through the size of the fracture origins.

Rongqi Li et al [2] Cubic boron nitride (cBN) has outstanding mechanical and thermal properties. The previous research focused on mechanical properties, to data, the thermal property of cBN has rarely been reported. In this work, a wide range of aluminum/cubic boron nitride (Al/cBN) composites were fabricated by pressure infiltration at 5.0 GPa and 960–1600 °C. The microstructure, phase composition, thermal conductivity and coefficient of thermal expansion of the Al/cBN composites were investigated. The results showed that a maximum thermal conductivity of 266 W/m K and the coefficient of thermal expansion of 4–6 × 10−6 K−1 which matches well to semiconductors, indicating that the Al/cBN composites are promised heat sink materials of high efficiency for the wide band gap semiconductors.

W. F. Ding et al. [3] Fabrication experiments of single-layer brazed grinding wheels were carried out using binderies cubic boron nitride (CBN) grains, Cu–Sn–Ti alloy and AISI 1045 steel. The brazing temperature was 900 °C and the dwelling time was 8 min. The microstructure of the joining interface was characterized. The performance of the grinding wheels was evaluated during high-speed grinding nickel super alloy. The fracture behavior of the abrasive grains versus the embedding depth was studied quantificationally. Results obtained show that good joining interface were formed among binderless CBN grains, Cu–Sn–Ti alloy and AISI 1045 steel dependent on the elemental diffusion and chemical reaction during brazing, which ensures firm hold to the abrasive grains. The grinding wheel with binderless CBN grains has exhibited evident advantages upon that with mono crystalline CBN grains in terms of grinding force and force ratio. The critical force acting on the binderless CBN gain with the exposing height of 50 and 705 is determined when the grain fracture takes place.

C E Baurer et al [4] Despite the increased use of aluminum–silicon alloys, grey cast iron is still the most abundant material in the heavy and automotive industries. Machinability of cast iron depends C E Bauer et al primarily on its microstructure but also on the amount of sand in casting, the distribution of chills and on the dimensional variations due to casting swell. P cBN tools are extremely successful in machining grey cast iron, particularly in machining homogeneous pearlitic castings.

Machining grey cast iron may become a major application of cBN coated tools, when available. PcBN tools are also among the very few tools capable of economically machining powder metal (PM) parts. Some of the listed new uses of PM technology in the automotive industry are the 3-11-V-6 engine at General Motors, as well as new transmissions, pressure plates, sprockets. Clutch hubs and turbine hubs at Ford. Hard turning is another expanding application of PCBN tools, which involves cutting steel with a Rockwell hardness of C-45 or above. At present most such parts are finished ground. Hard turning is being introduced to replace many of the present grinding processes. A PcBN tool cost per part is often twice grinding wheel costs, but the cost and maintenance of a grinding machine are generally 2–3 times greater than that of a lathe. Machining also offers faster stock removal, a one-step processing of complex parts and shorter set up time in small runs. The replacement of grinding processes with hard turning machining will affect future demand for PCBN (and cBN coated) tools.

Nihan Tuncer et al [5] Boron carbide–aluminum composites were produced by infiltrating aluminum alloys into porous boron carbide preforms at different temperatures under an argon gas atmosphere. Aim of this study was controlling the reaction between starting constituents by the use of various heat treatments. In order to reduce consumption of the starting constituents ($B4_C$ and Al) due to formation of reaction products, a thermal passivation process was employed to the as received $B4_C$ powders, which facilitates easier and faster infiltration of liquid Al into the porous compacts at temperatures as low as 900 ^{0}C.The Al constituent of the composites was then subjected to a precipitation hardening heat treatment to further improve their bending and compressive strength. This heat treatment was observed to result in a remarkable increase in both the bending and compressive strengths of the composites.

M. P. Bezhenar et al [6] X-ray diffraction analysis has been used to study the phase composition of composite materials produced by high pressure–high temperature (4.2 GPa, 1750 K) sintering of cBN and Al powders with diamond added to the reaction mixture. It has been shown that as a result of the reaction sintering depending on the relationship among the mixture components, in parallel with cBN and diamond, the composite materials may contain aluminum nitride, diboride, carboboride and carbide as well as solid solutions of boron and/or carbon based on the crystalline lattices of Al, AlN, and cBN. A possibility is shown of dispersion hardening of a composite providing the diamond content is below the threshold percolation. Along with diamond an increase in the resistance to abrasive wear of composites is responsible by the Al_3B_C phase, which is located at the phase boundaries.

Gurwinder Singh & Charanjeet Singh Kalra [7] 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 aim involved in designing hybrid composite materials is to combine the desirable attributes of metals and ceramics. Present work is focused on the study of behavior of Aluminum with Sic, Al_2O_3 and C particles composite produced by the squeeze casting technique. Different types of reinforcements are used. Hardness test & Impact test are performed on the samples obtained by the squeeze casting technique. Hardness tester is employed to evaluate the interfacial bonding between the particles and the matrix by indenting the indenter with constant load and constant time. Aluminum matrix composites have been successfully fabricated by squeeze casting technique with fairly uniform distribution of Sic, C and Al_2O_3 particles. It is found from the results that squeeze formed Al reinforced with Sic/Al_2O_3/C particle is clearly superior to base Al in comparison of Impact strength & Hardness. Dispersion of Sic, Al_2O_3 and C particles in aluminum matrix improve the hardness of the composite. It is also found that elongation tends to decrease with addition of reinforcement, which confirms that Sic, Al2O3 and C addition increases brittleness.

Sunday ARIBO et al. [8] The effect of high temperature on mechanical properties of silicon carbide particulate reinforced cast aluminum alloy composite has been investigated. 15% volume fraction silicon carbide aluminum alloy (6063) composite was cast by stir casting technique. The samples were machined to tensile, impact and hardness test samples and were tested at room temperature and elevated temperatures of 100°C, 250°C and 400°C. The results showed that the ultimate tensile strength, yield strength and hardness of the composite are enhanced at the elevated temperature. However the impact energy was observed to decrease with increase in temperature

Harish K.Garg et al [9] In the present study, based on the literature review, the machining of hybrid Aluminum Metal Matrix composite (Al/Sic/Gr and Al/Si10Mg/Fly ash/Gr) is discussed. These hybrid MMCs can easily be machined by EDM and a good surface quality can be obtained by controlling the machining parameters. These aluminum Metal Matrix composites with multiple reinforcements (hybrid MMCs) are finding increased applications because of improved mechanical and Tribological properties and hence are better substitutes for single reinforced composites. These materials are developed for bushes, bearings and cylinder liners in cast aluminum engine blocks.

Conclusions

Metal Matrix Composites (MMC) is composite materials comprising at least two components:

(i) A metal matrix

(ii) reinforcement. MMC are used to produce light weight and durable parts for ground transportation, electronics/thermal management, aerospace, defense, marine, nuclear and other industries.

To meet this objective the following steps has been systematically attempted Due to improved Thermal, Mechanical and Electrical properties the develop MMC composites can find application in advanced printed circuit board, Microelectronic packaging: ideal packaging material for components and devices that require advanced thermal management performance and in Radio frequency and microwave packaging

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