Characterization and Wear Response of Particulate Filled Metal Alloy Composites

(Al-17Si-Gr-C_f)

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Abstract

Metallographic studies several uniform copper coating and the distribution of reinforcements in the matrix alloy. Micro hardness and Tensile strength of the developed hybrid composites are higher when compared with that of the matrix alloy. The coefficient of friction of the developed Al-17Si-Gr-Cf hybrid composites is lower than that of the matrix alloy and other individual composites studied. Wear rates of the developed hybrid composites are lower than that of the matrix alloy and other individual composites studied. Increased content of reinforcements leads to lower wear rates of hybrid composites. Wear rates of hybrid composites at high temperatures are lower when compared to matrix alloy. The abrasive wear resistance of the developed hybrid composites is higher when compared to matrix alloy and other individual composites. The corrosion rate in 3.5%NaCl of the developed Al-17Si-Gr-Cf hybrid composite is higher when compared to the matrix alloy and other individual composites. It is observed that with increased content of the reinforcements in the matrix alloy, there is an increase in the corrosion rate.

Keywords:-Metal Alloy Composites, wear rates, Hybrid composite, Corrosion rate, micro hardness, tribological.

I. Introduction

History is often marked by the materials and technology that reflect human capability and understanding. Many times scales begin with the Stone Age, which led to the Bronze, Iron, Steel, Aluminum, and Alloy ages as improvements in refining, smelting took place and science made all these possible to move towards finding more advance materials possible. Progress in the development of advanced composites from the days of E glass / Phenolic radome structures of the early 1940's to the graphite/ polyimide composites used in the space shuttle orbiter-is spectacular. The recognition of the potential weight savings that can be achieved by using the advanced composites, which in turn means reduced cost and greater efficiency, was responsible for this growth in the technology of reinforcements, matrices, and fabrication of composites. If the first two decades saw the improvements in the fabrication method, a systematic study of properties and fracture mechanics was at the focal point in the '60s. Since then there has been an ever-increasing demand for newer, stronger, stiffer, and yet lighter-weight materials in fields such as aerospace, transportation, automobile, and construction sectors.

2 Constituents of Composites

A matrix binder and reinforcing filler constitute the principal components of a composite material.

2.1 Matrix

Matrix is the material that binds the filler and holds it. Any solid can be processed to embed and adherently grip a reinforcing phase in a potential matrix material. Essentially, a matrix material must be chemically compatible with reinforcement and with an interface between it and the reinforcement. Matrix generally is metals, ceramics and polymers. The matrix in the composite performs the following major roles:

Acts as a medium by which externally applied stress is transmitted and distributed to the reinforcements and only a small portion of the load is sustained by the matrix phase. Transfers the stress from individual reinforcement from surface damages as a result of abrasion or chemical reaction with the environment. It provides finish, color, texture, durability and other functional properties.

2.2 Metal Matrix

Metals are strong and tough. They can be plastically deformed and strengthened by a variety of metals mostly by obstructing the movement of linear defects called dislocations. The metal matrix may be aluminum and its alloys, copper and its alloys, titanium alloys, magnesium alloys and nickel-based superalloys. They are suitable for high-temperature applications (300 ^{o}C to 5000 ^{o}C) [Gayson & E.D. Martin 1983].

2.4 Ceramic Matrix

Ceramics are defined as products made from inorganic nonmetallic matrix processed at high temperatures at some time during their manufacture. The ceramic is used as matrix material owing to its high refractoriness, good chemical resistance, high hardness, and non-conducting properties. Some of the ceramics used are aluminum oxide, aluminum nitride, silicon carbide, silicon nitride, titanium carbide, and titanium nitride, etc. [P. Agarwal and C.T. Sun 2004]

2.5 Polymer Matrix

Polymers are much more complex than metals or ceramics. They are cheap and easily processable. The equipment required for the production of polymer composites is simple. They have lower strength and modulus, hence polymers have been widely accepted as a matrix and the reinforced polymers have qualified for structural applications. Because of predominantly covalent bonding, polymers are generally poor conductors of heat and electricity. They are more resistant to chemicals than metals. Structurally, they are giant chain-like molecules with covalently bonded carbon atom forming the backbone of the chain [Wheeltun John et al 1987].

2.6 Reinforcements

The reinforcement material is the one, which gives strength to the two-phase material. It improves and imparts stiffness. It prolongs the life of a composite by the improvement of mechanical and physical properties such as thermal and electrical conductivity. Based on aspect ratio (length to thickness) reinforcements are classified as,

- Fibers
- Whiskers
- Platelets and flakes
- Particulate

The studies related to them. Most of the re- search is referred to Nickel and Titanium intermetallic compounds, also known as NiTi or Nitinol alloys, which occupy the majority of the shape memory products market.

Surveys indicate that a high percentage of all mechanical components value, manufactured in the world, comes from machining operations and that annual expenditure on machine tools and cutting tools are several billion euros for industrially developed countries [1,2]. Manufacturing technology is driven by two very important factors, which are closely interconnected, namely better quality and reduced cost. Modern industry strives for products with dimensional and form accuracy and low surface roughness at acceptable cost while, from an economic point of view, machining cost reduction achieved through the increase of material removal rate and tool life without compromising surface integrity, especially for hard-to-machine materials like SMAs is highly desirable. Applications refer mostly to actuators and implants, but there have been more than 10,000 SMA related patents in the USA only and more than 20,000 worldwide, in various industrial areas [3]. Most applications refer to the micro-world regime for state-of-the-art products requiring accuracy, surface integrity and complex shapes at acceptable cost. Machining can provide all these characteristics and perform better compared to other manufacturing processes. However, there are limitations connected to materials and tools properties.

2. Literaturer review

Amanda McKiea et. 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.

Zhengyang Li et al [2] In this paper, synthesis of novel super hard and high performance composites of titanium silicon carbide - cubic boron nitride (Ti3SiC2-cBN) were evaluated at three different conditions,

(a) High pressure synthesis at ~ 4.5 GPa,

(b) Hot pressing at ~ 35 MPa, and

(c) Sintering under ambient pressure (0.1 MPa) in a tube furnace.

From the analysis of experimental results, authors report that the novel Ti3SiC2-cBN composites can be successfully fabricated at 1050 °C under a pressure of ~ 4.5 GPa from the mixture of Ti3SiC2 powders and cBN powders. The subsequent analysis of the microstructure and hardness studies indicates that these composites are promising candidates for superhard materials.

C. Thiagarajan et al. [3] The investigations of this study indicated that the grinding variables; wheel velocity, work piece velocity, feed and depth of cut are the primary influencing factors which affect the surface integrity of Al/Sic composites during cylindrical grinding. Based on the experimental results and discussions, the following conclusions are drawn:

(a) Better surface finish and damage free surfaces are obtained due to low grinding force at high wheel and work piece velocities with white Al2O3 wheels during cylindrical grinding

(b) The surface finish and damaged surfaces are found to be high at high feed and depth of cut during cylindrical grinding;

(c) The experimental work demonstrates that the tangential grinding force developed during cylindrical grinding can be calculated from power measurements of the grinding wheel motor, using a Variable- Frequency Drive (VFD); and

(d) The approach presented in this paper for cylindrical grinding of Al/sic composites can be extended with super abrasive grinding wheels like diamond and CBN

S.Prabagaran et al. [4] Aim of this work is to do a viable machinability study by experimental investigations on surface roughness and swarf formation in turning of AA6061 aluminum alloy (100%), AA6061-B4C (90% and 10%) and AA6061-B4C-Gr (87%-10% and 3%) hybrid composites. Experiments were conducted with different cutting conditions using Carbide, CBN (Cubic Boron Nitride) and PCD (Poly Crystalline Diamond) tools. Surface roughnesses are more for carbide tools in comparison with PCD tools which are minimum. PCD tools perform better than cBN and carbide tools. This is due to the daubing effect and dismissal of softer and amorphous Graphite particles on the surface of the composite specimen, which produces pits on the machined and hence reduces the surface finish level. On the other hand graphite particulated composite produces discontinuous chips that led to the smooth machining. PCD tools are better than carbide and coated carbide tools in the reduction of surface roughness.

M. P. Bezhenar et al.[5] Physical mechanical properties (fracture toughness, hardness and its dependence on the temperature) have been considered of samples of composites of the cBN–Al system produced at a pressure of 4.2 GPa and temperature of 1750 K with the variable aluminum content of the reaction mixture and time of sintering. The effect of the phase composition and real crystalline structure on the composite properties has been shown.

Xiao-Tao Luo et al. [6] When mechanical alloying process is employed to synthesize composite powders strengthened by particle dispersion the powders tend to fracture into small segments, especially when high content of ceramic particles is added. In the present work, a step-fashion mechanical alloying (MA) method was developed to synthesize 40 vol.% cBNp/NiCrAl composite powders with both cBNp uniform dispersion in the metal alloy matrix and desirable particle size distribution. The effect of MA time on the particle size, microstructure, grain size and micro hardness of the composite powder was investigated. The morphology and cross-sectional microstructure evolution of composite powders during milling were characterized by scanning electron microscopy (SEM).

The change of the grain size of the alloy matrix phase with milling time was estimated based on X-ray diffraction analysis (XRD). It was found that after 40 h of milling the nanostructured composite powder with a mean particle size of ~22 μm and a narrow distribution was obtained. Moreover, the SEM examination showed that cBN particles were uniformly distributed in the nano structured NiCrAl matrix. Finally, the milling mechanism of the proposed step-fashion MA was discussed.

M. P. Bezhenara et al. [7] It has been found by X-ray diffraction and structure analyses that in the reaction sintering of cubic boron nitride composites from the cBN+8 % Al+26 % Tic mixture at high pressure and temperature (4.2 GPa, 1750 K) in the binding ceramics composition in addition to AlN, there forms a TixAl1–xB2yN2 (1–y) solid solution, in which titanium and aluminum atoms generate a skeleton, whose composition is close to the equimolar one and boron and nitrogen atoms are distributed randomly in graphite like networks.

Dunia Abdul Saheb [8] Metal Matrix Composites (MMCs) have been used in several applications in aerospace and automotive industries Although several technical challenges exist with casting technology. Achieving a uniform distribution of reinforcement within the matrix is one such challenge, which affects directly on the properties and quality of composite. In the present study a modest attempt has been made to develop aluminum based silicon carbide particulate MMCs, graphite particulate MMCs with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material. Experiments have been conducted by varying weight fraction of SiC, graphite and alumina (5%, 10%, 15%, 20%, 25%, and 30%), while graphite weight fraction 2%, 4%, 6%, 8% and 10% keep all other parameters constant. The results indicated that the 'developed method' is quite successful to obtain uniform dispersion of reinforcement in the matrix. An increasing of hardness and with increase in weight percentage of ceramic materials has been observed. The best results (maximum hardness) have been obtained at 25 % weight fraction of sic and at 4% weight fraction of graphite.

J.Jenix Rino et al. [9] 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 aluminum metal matrix composites with hybrid reinforcement.

Asif M et al.[10] The present study deals with the investigation of dry sliding wear behavior of aluminum alloy based composites, reinforced with silicon carbide particles and solid lubricants such as graphite/antimony tri supplied (Sb2S3). The first one of the composites (binary) consists of Al with 20% Silicon Carbide particles (SiCp) only. The other composite has SiCp and solid lubricants: Graphite + Sb2S3 (hybrid composite) at solid state. Both composites are fabricated through P/M route using "Hot powder performs forging technology". The density and hardness are measured by usual methods. The pin-on-disc dry wear tests to measure the tribological properties are conducted for one hour at different parameters namely loads: 30, 50 and 80N and speed: 5, 7 and 9m/s. The tested samples are examined using scanning electron microscope (SEM) for the characterization of microstructure and tribolayer on worn surface of composites. The results reveal that wear rate of hybrid composite is lower than that of binary composite. The wear rate decreased with the increasing load and increased with increasing speed. The results of the proposed composites are compared with iron based metal matrix composites (FM01N, FM02) at corresponding values of test parameters. These iron based metal matrix composites are also fabricated by P/M route using 'Hot powder perform forging technology'. The comparative study reveals that the proposed composites have lower friction coefficient, less temperature rise and low noise level; however they have little higher wear rate. It is concluded that the hybrid composite has acceptable level of tribological characteristics with blacky and smooth worn surface

Conclusions

Sic particulate or whiser-reinforced aluminum alloys are very attractive for applications requiring high stiffness coupled with a comparatively light weight. The dispersion strengthened Al alloys produced through the rapid solidification processing/powder metallurgy route demonstrate superior elevated temperature strength and microstructural stability, extending the useful service temperature of Al alloys to 350 °C. However, low ductility and poor fracture toughness levels is the problem. However incorporation of cBN and PCD can improve the ductility, facture toughness and hardness of Al alloys.

Incorporation cBN and PCD to the base metal will improve the thermal conductivity and damping chartestics of the MMC composites, as cBN and PCD has good thermal and damping properties. This can make the alloy composites to use in the serve damping conditions.

Improved Mechanical Properties like Shear stress, Ultimate Tensile Strength, Hardness, Fracture Toughness, compressive Strength, Impact Properties as compared to base metal and can obtain the best result in all Particulate–alloy combinations.

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