A comprehensive study of Copper based hybrid metal matrix composites (MMC) on the basis of their Structural and Mechanical properties

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ABSTRACT

For electrical sliding contact applications, additional characteristics such as high tribological capabilities and resistance to wear are crucial. Various other characteristics are also necessary for various applications, in addition to high electrical conductivity. By mixing graphite into a copper matrix, self-lubrication may be generated. Microwave hybrid sintering effectively produces composites reinforced with graphite, TiC, and a copper metal matrix. An analysis of the microstructure of the copper matrix revealed a homogeneous distribution of reinforcement. The volumetric heating of hybrid heating was assisted by the uniform surface and depth hardness of sintered composites. Agglomeration occurs as the concentration of graphite rises, leading to less dense composites and ineffective heating. Composites may be dandified by TiC up to a 10% volume percentage, after which the benefits of densification cease. Despite the copper matrix's graphite reinforcing, TiC from 5–15 vol.% enhanced hardness. Stir casting and sand moulding processes were employed to generate aluminum-copper alloy composites, with starch acting as a binder. Composites of aluminum-zinc oxide and titanium-oxygen improved by abrasion.

Keywords: Metal Matrix Composites (MMC's); Microstructure, Density, Hardness; Wear

INTRODUCTION

To enhance their mechanical and tribological properties, a novel family of aluminum-based composites is being widely used. These composites are doped with various metal and ceramic reinforcements. Strong strength and excellent ductility can be achieved using copper reinforcement of alumina. Since the components used to create these composites are recycled and classified as fresh scrap, find that the combination of sinter and forging techniques may simplify processing and lower manufacturing costs. Copper and alumina reinforcement of a novel composite was motivated by the use of linkage/connector components in aerospace applications. It is therefore imperative to do research on high-tech composites with copper matrices. One way to produce self-lubrication is to combine graphite with a copper matrix[1-2]. When two or more materials, known as constituent materials, are joined, they form a composite with properties that are distinct from those of any of the constituent elements. The final construction maintains the integrity of its constituent parts. Matrix and reinforcement are the two most common types of component materials.

Particle-reinforced composites have reinforcement in the form of particles with diameters that are all nearly the same. High-temperature performance, friction, wear resistance, and shrinking are all areas where particle fillers are useful. This means that a particle reinforcement will increase stiffness but not overall strength. Reinforcements in fiber-reinforced composites have lengths greater than their cross sectional size. Instead of using chemicals to alter a material, engineers may use fibrous reinforcement to tailor it to certain uses. Composites with long fibers are known as continuous fiber reinforced materials (CFRM), whereas those with shorter fibers, such as staples, are known as discontinuous fiber reinforced materials (DFRM). Enhanced strength qualities may be achieved by orienting fibers in just one direction, as is done in continuous fiber composites. The short fiber length in short fiber composites is not so short that the fibers lose their fibrous character or so long that they easily mix with one another. Composites with evenly distributed short fibers provide consistent reinforcing. [18].

Composites are lighter than metal and used for aircraft bodies. Space-bound satellite beams with benches made of composite materials. Composites have many advantages over solids due to their low linear thermal expansion. Here, the matrix serves as the foundation, and the abrasives as the sharpening mechanism. The specific modulus (the ratio of stiffness to density) of unidirectional composites is roughly three to five times that of steel and aluminum. Life costs are decreased because to the composite fibers' strong resistance to corrosion. A composite's elimination of joints or fasteners allows for simplified, integrated design. Excellent structural damping properties may be engineered into fiber-reinforced composites. Because of their high melting point, low specific heat, good electrical conductivity, strong resistance to corrosion, low manufacturing cost, high strength, low fatigue, and low melting point. Cables, wires, electrical contacts, and many other components that need to conduct electricity rely heavily on pure Cu[19].

Composites made from a metal matrix also include inorganic or ceramic components. In most cases, reinforcements are added to a metal so that it has better mechanical qualities. The characteristics of MMCs are very sensitive to the particle dispersion. Metal matrix composites increasingly use copper, magnesium, and aluminum as their foundation metal. The primary benefits of MMCs lie in the fact that, with careful selection of matrix and reinforcement volume fractions, the physical and mechanical characteristics may be dominated. When compared to their superior performance, the manufacture of composites is a cheap procedure. Despite the abundance of written material on the issue, scientists continue to investigate aluminum matrix composites (AMCs)[20].

The physical and mechanical features of composites, and how they are modified by TiC and graphite reinforcement, are also explored at length. We see a schematic depiction of the microwave sintering equipment put to use in this investigation. A 3.2 kW multimode 2.45 GHz industrial microwave furnace with four "mode stirrer" devices is employed. The multimode cavity is the center around which the hybrid sintering arrangement is formed.[21]

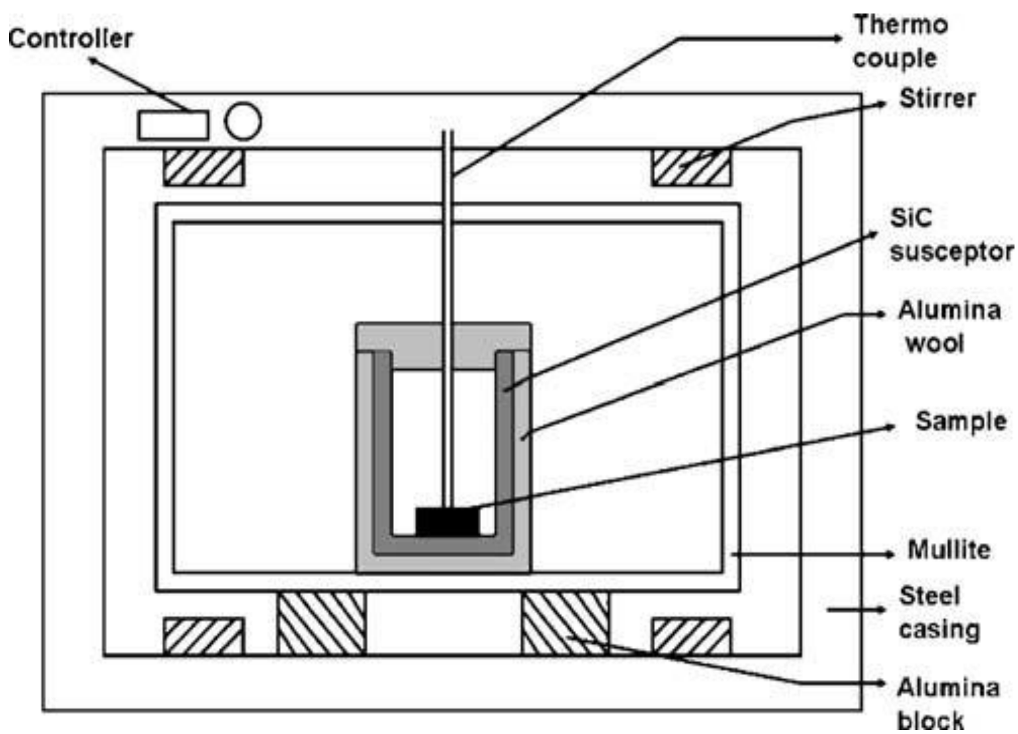

Fig. 1- Sintering setup of an Microwave

LITERATURE REVIEW

The impact of the two-step stir casting technique on the mechanical characteristics of an AA7175 composite reinforced with silicon nitride and graphene. Combining numerous matrices and reinforcements is a possible problem that continues to be present in the development of MMCs. Because of its remarkable qualities, such as enhanced resistance to corrosion and wear, superior weldability, and high thermal conductivity, copper alloy-based matrix composites are widely used in a wide range of automotive and electrical components [1-5].

examined the mechanical and frictional properties of copper matrix composites and showed that they might be used as high-speed train brake pad materials. The user has provided a written explanation but not a numerical reference. In order to create a unique material with the necessary qualities, several materials with different physical properties are combined to create composites. The demands placed on traditional materials are more stringent in a number of industries, which is why new materials are always being developed to meet these needs. Owing to the widespread emphasis on lightweight design in a number of modern Metal Matrix Composites (MMCs) applications, aluminium and its alloys have received a great deal of attention in research and development. It has not been studied how to strengthen composites made of copper and aluminium alloys using sand mould casting, stir casting, or temporary wax patterns[6].

No study has combined various abrasive particle sizes to create aluminum-copper metal matrix composites. The homogeneous depth and surface hardness of the sintered composite helped with the hybrid heating's volumetric heating capability. The incorporation of Si3N4 into Graphane results in an augmentation of the material's hardness, wear rate, ductility, and strength. The incorporation of SiN reinforcing elements into a Cu-Sn matrix at a weight percentage of 7.5% resulted in significant enhancements in several mechanical properties. In particular, there was a 41% increase in hardness, a 33% rise in ultimate tensile strength, a 29% increase in yield strength, and a 23% increase in ductility. The scanning electron microscopy (SEM) analysis shows that the particles utilised as reinforcements are distributed uniformly. The hybrid combination performed better in wear and mechanical characteristics than the metal matrix composite made solely of aluminium. AMC is produced by stir casting at a reduced cost per unit.Stir casting was discovered to be beneficial for hybrid composites by Srivastava, et al. By adding reinforcing elements, stir casting becomes harder [7].

The mechanical properties and manufacturing of stir-casting AA6061 reinforcements of SiC and Al2O3 were assessed by Khanduja,et al. The tensile strength, density, and hardness of AA6061/SiC/Al2O3 composites are all increased by reinforcement.The hardness and wear resistance of LM25 are increased by 10% compared to a single reinforcement when it has active carbon and mica reinforcements.The physical and mechanical characteristics of Al6061/Al2O3 were examined by S. Ram Kumar et al. Aluminum oxide and silicon carbide are stir-cast to make this composite. Al6061 doped with 2.5% Al2O3 and 5% SiC had enhanced mechanical characteristics [8].

By utilizing the stir-cast process, copper particles are dispersed in an aluminum matrix, creating a composite metallic material (CMM) whose behavior is comparable to that of an alloy with the same composition. Copper concentrations between 5 and 15 wt% are investigated as a means of examining the impact of particle composition. The strength rose and decreased with the addition of reinforcing content, which was shown to improve hardness in both cast and homogenized circumstances. Journal bearing metals were studied by Ünlü, B. S. for their mechanical and tribological qualities. He discovered that AlCuMg2, ZnAl, and SnPbCuSb all had higher wear values than CuSn10 and CuZn30. In addition, he looked into CuSn10's mechanical qualities[34].

Compared to ZnAl and SuPbCuSb, bearing materials CuZn30 and AlCuMg2 performed better [9].
After synthesizing copper and graphite in a stir casting process, Jitendrakumar et al. found that a composite containing 15 weight percent graphite had better mechanical and tribological characteristics than either pure graphite or copper containing 10 weight percent graphite. The composite's impact strength falls because graphite is a weak and brittle material. Adding graphite reinforcement to a copper-based composite increases its wear resistance dramatically.Using powder metallurgy, he investigated the mechanical characteristics of a Coppergraphite composite composed of metal matrix and discovered that electrical conductivity rises with decreasing graphite concentration and density reduces with increasing graph content.Aggregation of graphite particles in molten copper alloy may be prevented by traditional mechanical stir casting. Copper matrix hybrid composites were created and characterized[10].

Additional reinforcement was provided by graphite and other soft phases in order to circumvent this issue. Because of its excellent electrical and thermal conductivity, graphite is a perfect additive to copper composites, improving their machinability. Die cast aluminium alloy specimens (6061) with copper content percentages of 4%, 6%, 8%, and 10% will be used in this investigation. Up to eight weight percent (wt%) of copper particle, Al alloy 6061 with Cu MMC has a greater hardness; beyond that, it declines. By adding copper particles, the composite's tensile and impact strength reached 8% weight percentage[11].

In tests, the material's hardness and ultimate tensile strength were enhanced by SiC particles (5, 10, and 15 Wt%). Al-SiC composites covered with copper have superior mechanical qualities than those that aren't. The results demonstrated that in Al-SiC MMCs, copper-coated SiC reinforcements improve wear resistance and SiC composition lowers wear rate. Cu-reinforced SiC particulate composites were investigated with using unmilled and as-milled Cu powder at 10, 20, 30, and 40% reinforcement content. metal-powder technique. X–SiC-Cucomposites having more volume. Wear resistance is % better in SiC. All developed Cu-SiC composites outperform pure Cu in wear resistance. Manvandra Kumar Singh studied dual-reinforced copper-based hybrid composite mechanical properties [12].

Thus, ZrO_2 are added as reinforcement to the copper matrix at a predetermined amount to achieve the hybrid composite's superior mechanical properties. Optical microscopy, SEM, and a hardness test reveal the developed hybrid composites' properties. The matrix contains both reinforcements, hence these descriptions indicate a hybrid material. Copper-based hybrid composites are tougher than commercial copper matrices. SiC at 3, 5, and 10 weight percent and graphite at 1 weight percent strengthen high-purity copper scrap. Micro hardness, friction, and wear experiments were done on cast Cu SiC-Graphite composites. Metallography shows uniform reinforcing distribution in matrix metal. Hybrid composites wear better due to higher SiC content. Hybrid composites offer lower friction than Cu-SiC composites because graphite is added[13].

Friction stir processing materials' mechanical and microstructural properties to manufacture hybrid Cu-SiC-Zn composites. This research investigated mechanical, microstructural, and dislocation density behavior across pass numbers to discover how pass addition affects them. Higher passes seemed to distribute SiC particles and intermetallic phases more evenly. Dislocation density simulations demonstrate that intermetallic phases and SiC particles may enhance dislocation values. Dislocation density and micro hardness measures demonstrate that composites outperform base metal[14].

Powder metallurgy combines composite powder, compacts, sinters, and hot presses it to make hybrid nanocomposites. Nanocomposites with low densities were possible due to MWCNTs and SiC's low concentrations. Nano composites are 1.5 times tougher than pure copper under the same conditions. Nano composites' electrical conductivity decreased due to grain refining from several reinforcements. Wang et al. found that grain refinement strengthening outperformed particle dispersion strengthening in a Cu-based composite reinforced with Al_2O_3 particulates. The mechanical characteristics of stir-cast composites with a pure copper matrix and WC-Al_2O_3-Cr and WC-ZrO_2-Cr reinforcements were studied. The mechanical properties of copper/WC hybrid composites produced by liquid metallurgy with highly stressed stainless steel chips were investigated[15].

A microstructure-based model to study metal fracture mechanisms and A359/SiC MMC deformation, a stirrer mechanism to test a ZrB_2-Si_3N_4 reinforced AMMC. Nineteen They discovered that the primary causes of material deformation and failure may be identified using the microstructure-based model. SiC exhibits a higher yield strength in aluminium metal matrix composites with 10 m particle size than those with 50 m particle size.7. Yield strength is also increased by strain rate. Several studies on enhancing aluminium matrix composites (AMCs) using various casting techniques and abrasive particles (SiC, TiC, B_4C, ZrO_2, TiO_2, etc.) were discovered in the reviewed literature. It has not been studied how to create composites reinforced with titania (TiO_2) and zirconia (ZrO_2) using stir casting, sand mould casting, or temporary wax pattern.To far, no published study has created aluminum-copper metal matrix composites using varying-sized abrasive particles. Constructing a special aluminium matrix composite and researching its mechanical characteristics sounds like a smart concept. Titania (TiO_2) is inexpensive, non-toxic, and chemically stable, which makes it a popular ingredient in paints, ointments, sunscreens, toothpaste, sensors, and other products. Good lubricant dispersion stability, high strength, hardness, wear resistance, and chemical resistance are among the qualities of zirconia (ZrO_2). Utilise refractory materials and synthetic abrasives such as ZrO_2 and TiO_2. ZrO_2 improves the fracture strength and basic matrix creep resistance in MMC. MMC enhances mechanical characteristics and corrosion resistance when TiO_2 is employed as a reinforced particle. To enhance composite wear, ZrO_2 and TiO_2 are reinforced into the base matrix. This reinforcement prevents bending of the surface due to abrasion and dry sliding[16].

AZ91 MMC reinforced with SiCp, they noticed that heat treatment might change the microstructure of the composite to improve its mechanical properties and $Mg_{17}Al_{12}$ kinetics.The array of component molecules in the composite seemed to be in three dimensions, and SEM revealed a uniform distribution of reinforcement particles in the base matrix. The elemental proportion of the composite was ascertained using Energy Dispersive Spectroscopy (EDS). The abundance of composite components was calculated using EDS. Using SEMs and universal testing apparatus, the mechanical characteristics, fractography, and microstructure of ECA Ped composites. Utilized fractography, hardness, and tensile strength to compare the hybrid composites. Recent studies conducted in poor nations have concentrated on the production of inexpensive composite materials based on aluminium. Researchers from the area are looking on burning and recycling ashes. Particle reinforcement for MMCs using agro-waste. Bamboo leaf, crushed nut shell, and coconut shell. Agro-waste may include sizable amounts of silica and other refractory oxides, according to chemical studies. Compared to manufactured reinforcements like SiC and Al_2O_3, these agro-waste materials are less dense. AMC strength is only moderate even when significant volume percentages of reinforcements are applied, according to several articles. This is the only significant obstacle to reinforcing aluminum-based composites using ashes from agricultural waste. This was a result of the most common element in agro-waste ashes, silica[17].

METHODOLOGY

A metallurgical microscope was employed to examine the microstructure of the specimen. The experiment relied on an optical microscope with the model number "Leica DM2700M." Etching of the specimen was done for 10 seconds by using a solution of 25 ml of hydrochloric acid, 100 ml of ethanol, and 5 g of ferric chloride before being subjected to microstructural examination. Morphological examination of the specimen was carried out by using SEM coupled with EDS. The ZEISS EVO-MA was the SEM model used in this analysis. The SEM experiment employed an accelerating voltage of 20.0 kV. To increase their conductivity, all samples were treated with platinum.

For determining the elements in the fabricated composites EDS was being employed upon. Density of the specimen was determined by using the below mentioned equation $\mathbf{1}\boldsymbol{pc}$ = Mgr$\mathbf{1}\boldsymbol{Pgr}$ + Mcu$\mathbf{1}\boldsymbol{Pcu}$ Where Mgr is the mass fraction of the Graphite-TiC, Mcu is the mass fraction of the Cu, Pgr is the density of Graphite-TiC (2.07 g/cm3), and PCu is the density of copper (8.96 g/cm3). Hardness of the specimen was determined by using Rockwell Hardness Tester (TRS, Fine Testing Machine, India) on B-scale having major load of 100 kgf and minor load of 10 kgf. Intended target was indented with a hardened steel ball measuring 1/8 inch. Hardness measurement was carried out at 4 different places and a mean was taken for all the readings. UTM was used to assess the compression strength of the specimens (Model no. SOM205, Neelam Engineering Company, India).

CONCLUSION

In the current investigation, it is observed that the mechanical, tribiological and corrosion properties of the metal matrix hybrid composites (MMHCs) developed by any processes shows better results as compared to its matrices. So, in the current scenario the MMHCs can be most appropriate engineering materials for various applications in the fields of aerospace, automobile, railways, marines etc. Copper alloy (C87600) matrix hybrid composites were successfully fabricated by stir casting using SiC-Gr and WC-Gr particles, from which the following conclusions are made:

i. Microwave hybrid sintering efficiently creates composites with copper metal matrix, TiC, and graphite reinforcements. Copper matrix microstructure investigation demonstrated uniform reinforcing distribution.
ii. The microstructure, as well as the wear resistance and ductility parameters, must be further enhanced by enhancing the doping procedure and suitable powder combination preparation conditions. That is to say, more time spent ball milling will help produce a finer and more uniform particle dispersion throughout the matrix.
iii. Stir casting and sand moulding techniques were used to create aluminum-copper alloy composites, with starch acting as a binder. Composites of aluminum-zinc oxide and titanium-oxygen enhanced by abrasion.
iv. Modifications in the Gr.-TiC reinforcing % had minimal effect on the hardness of matrix matrix composites (MMCs).
v. The copper and ceramic reinforcements did not produce any intermetallic compounds.Copper hybrid MMCs' micro-hardness and tensile strength significantly improved as a result of improved interfacial bonding and wettability of ceramic particles with molten alloy.

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