



Investigation of Mechanical Behaviour of Copper Matrix Composite Material Reinforced With TiB_2

¹A.Anbarasan A, ²Dosin Davidson, ³J.Shophen, ⁴Sinsha

¹Assistant professor, ^{2,3,4}Student

¹²³⁴Department of Mechanical engineering, Loyola Institute of Technology, Chennai, India.

Abstract

Composites are manmade materials which are the combination of two or more elements whose properties cannot be achieved when the materials are separate. Specifically, Metal Matrix Composites (MMCs) are industry-oriented materials of recent times due to their superior and tailorable properties. Current researches are concentrated towards Nano Metal Matrix Composites (NMMCs) due to their distinctive properties like high strength, low density, better tribological and corrosion properties. Applications in marine and other salt water environments demand the usage of inherently corrosion resistant materials like aluminium, copper etc. Current challenge is to develop composites that possess better corrosion and wear resistance for use in marine applications. Generally, soft copper (Cu) matrix is reinforced with hard oxides, carbides and borides for better mechanical properties. This research paper describes the enhancement of mechanical behaviour of the Copper (Cu) matrix composite by reinforcing Titanium diboride (TiB_2). The main objective of this study was to reduce the weight and cost of the hybrid composites. The weight percentage of low density samples were prepared by the addition of TiB_2 in weight percentages of 3, 4 and 5 in the Cu matrix. From the mechanical characterization, it was identified that there is an increase in microhardness and compressive strength with the addition of TiB_2 particles. It can be understood that the TiB_2 particles occupy substitutional type reinforcement in the Cu matrix.

Keywords-Reinforced Composite, powder metallurgy, Tensile Test, Optical Microscopy.

1.INTRODUCTION

A Composite is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials. When two or more different materials are combined, the result is a composite. The first uses of composites date back to the 1500 B.C. when early Egyptians and Mesopotamian settlers used a mixture of mud and straw to create strong and durable buildings. Straw continued to provide reinforcement to ancient composite products including pottery and boats. Later, in 1200 AD, the Mongols invented the first composite bow. Using a combination of wood, bone, and "animal glue," bows were pressed and wrapped with birch bark. These bows were powerful and accurate. Composite Mongolian bows helped to ensure Genghis Khan's military dominance.

Aircraft alloy materials and processing technology has been advancing steadily with each new aircraft model. Important alloys in commercial transport applications include high-performance aluminium alloys, high-strength steels, and titanium alloys. Significant progress is being made in developing alloys with improved strength, toughness, corrosion resistance, and machinability. Advances have been achieved primarily through incremental improvements to already developed alloys. Manufacturing process development has been emphasizing low-cost approaches such as net-shape processing (casting and forging), improved forming methods, and high-speed machining. This chapter describes developments and trends in metallic alloy materials and processes. Much of the early work on metal-matrix composites (MMCs) involved aluminium-matrix alloys. Recently, matrices based on titanium alloys and intermetallic of titanium and aluminium ($\gamma TiAl$) has received much interest. There are a variety of types and morphologies of reinforcements used in MMCs, principally high-melting-point ceramics, such as SiC or Al_2O_3 , in the form of discrete whiskers, particles, or continuous fibers. The major benefit of MMCs over monolithic alloys is their higher strength, elastic modulus, and fatigue crack initiation resistance at the expense of lower toughness. The major emphasis in research has been to achieve improved ductility and toughness in discontinuously reinforced MMCs and improved toughness in continuously reinforced MMCs with no

loss in strength. Unfortunately, the costs of producing MMCs are high. In MMCs with continuous reinforcement, key issues include cost, processing, and machinability of useful shapes. Continuously reinforced MMCs provide the greatest strength and stiffness at premium cost. Landing gear on advanced aircraft can use continuously reinforced MMCs for reduced weight and increased environmental resistance.

2.MATERIALS AND PROCEDURES

2.1 Oxygen Free Copper (C10200)

C10200 – also known as oxygen-free (OF). While OF is considered oxygen-free, its conductivity rating is no better than the more common ETP grade below. It has a 0.001% oxygen content, 99.95% purity and minimum 100% IACS conductivity. For the purposes of purity percentage, silver (Ag) content is counted as copper (Cu). For industrial applications, oxygen-free copper is valued more for its chemical purity than its electrical conductivity. OF/OFE-grade copper is used in plasma deposition (sputtering) processes, including the manufacture of semiconductors and superconductor components, as well as in high-vacuum devices such as particle accelerators. In any of these applications, the release of oxygen or other impurities can cause undesirable chemical reactions with other materials in the local environment.

Density	8.96 g/cc
Electrical Resistivity	1.673 $\mu\Omega$ -cm @ 20°C
Tensile Yield Strength	210 MPa
Vickers Hardness	369 Mpa
Thermal Conductivity	401 W/m-K
Melting Point	1085°C

Table 2.1.1 Mechanical properties of 1 Oxygen Free Copper

2.2 Titanium Diboride (TiB₂)

Titanium diboride (TiB₂) is an extremely hard ceramic which has excellent heat conductivity, oxidation stability and wear resistance. TiB₂ is also a reasonable electrical conductor, so it can be used as a cathode material in aluminium smelting and can be shaped by electrical discharge machining. Current use of TiB₂ appears to be limited to specialized applications in such areas as impact resistant Armor, cutting tools, crucibles, neutron absorbers and wear resistant coatings. Thin films of TiB₂ can be used to provide wear and corrosion resistance to a cheap and/or tough substrate.

Element	Titanium	Boron
Content %	68.88	31.15

Table 1: Chemical Composition of Titanium diboride (TiB₂)

2.3 Powder metallurgy:

It is a term covering a wide range of ways in which materials or components are made from metal powders. PM processes can avoid, or greatly reduce, the need to use metal removal processes, thereby drastically reducing yield losses in manufacture and often resulting in lower costs Powdered metal and discontinuous reinforcement are mixed and then bonded through a process of compaction, and thermo-mechanical treatment via hot isostatic pressing or extrusion.

Process 1:

Powder compaction is the process of compacting metal powder in a die through the application of high pressures. Typically, the tools are held in the vertical orientation with the punch tool forming the bottom of the cavity. The powder is then compacted into a shape and then ejected from the die cavity. In a number of these applications the parts may require very little additional work for their intended use making for very cost efficient manufacturing. The density of the compacted powder increases with the amount of pressure applied. There are four major classes of tool styles: single-action compaction, used for thin, flat components; opposed double-action with two punch motions, which accommodates thicker components; double-action with floating die; and double action withdrawal die. Double action classes give much better density distribution than single action. Tooling must be designed so that it

will withstand the extreme pressure without deforming or bending. Tools must be made from materials that are polished and wear-resistant. Better workpiece materials can be obtained by repressing and re-sintering.



Fig 1: Powder Compacting

Process 2:

Sintering

After compaction, powdered materials are heated in a controlled atmosphere in a process known as sintering. During this process, the surfaces of the particles are bonded and desirable properties are achieved. Sintering of powder metals is a process in which particles under pressure chemically bond to themselves in order to form a coherent shape when exposed to a high temperature. The temperature in which the particles are sintered is most commonly below the melting point of the main component in the powder. If the temperature is above the melting point of a component in the powder metal part, the liquid of the melted particles fills the pores. This type of sintering is known as liquid-state sintering. A major challenge with sintering in general is knowing the effect of the process on the dimensions of the compact particles. This is especially difficult for tooling purposes in which specific dimensions may be needed. It is most common for the sintered part to shrink and become denser, but it can also expand or experience no net change.



Fig 2:Sintering

Highly competitive market requires high quality products at minimum cost. Industries in which the cost of raw material is a huge amount of the cost of finish goods, high efficiency can be achieved through proper selection and use of the materials. The term “nonferrous” refers to all metals which have elements other than iron as their base or principal constituent. Materials selected for matrix and reinforcement, powder processing and characterization, methodology of fabricating copper matrix composites used for mechanical properties-based tests are discussed.

3. RESULTS AND DISCUSSION

3.1 Micro-hardness

The micro-hardness evaluation on test samples was conducted with the help of hardness testing machine with a minimum number of 0.01 mm. Vickers scale could be used to monitor the readings. The load of 0.1 Kg of force, 10 s of dwelling time, and measuring unit was 0.1 Kgf. The sum of 3 results that were considered for study. The observations provided for in Table 1 and discussed in the next section.

S.No	Composition	Hardness			
		1	2	3	Mean
1	Cu100%	53	50	48	50.34
2	Cu 97%+ TiB ₂ 3%	52	55	54	53.67
3	Cu 96%+ TiB ₂ 4%	63	59	61	61
4	Cu 95%+ TiB ₂ 5%	63	65	60	62.67

Table 3.1.1 Hardness Results for different % of TiB₂

3.2 Compression strength

The compression test of Cu matrix composites were carried out using universal testing machine where the compression plate compress the work samples, the load increases gradually and compression test is computed using datalogger. The compression load was stopped before the initial crack formation. The Cu/2wt.%TiB₂ composite shows a higher compression strength than alloy and another composites.

Compression Test:(Cu100%)

Test Parameters	Observed Values
Compression Strength(Mpa)	127
Compression Load(kN)	12.48

Compression Test: (Cu 97%+ TiB₂ 3%)

Test Parameters	Observed Values
Compression Strength(Mpa)	144
Compression Load(kN)	14.22

Compression Test: (Cu 96%+ TiB₂ 4%)

Test Parameters	Observed Values
Compression Strength(Mpa)	92
Compression Load(kN)	8.910

Compression Test: (Cu 95%+ TiB₂ 5%)

Test Parameters	Observed Values
Compression Strength(Mpa)	92
Compression Load(kN)	8.910

4.CONCLUSION

Copper matrix composites reinforced with TiB₂ were prepared via powder metallurgy process. The impact of TiB₂ on mechanical performance of the composite was investigated. The mechanical properties of copper matrix composite are examined. In particular, machinability applications will contribute to its practical use in the industry. In addition, these composite materials produced;

- Determination of strength and hardness
- Determining the effect of these methods on mechanical properties by using powder metallurgy.

It is thought that studies such as these can be used to expand the usage areas of these composites and to obtain optimum utilization from these composites. In this study, Cu based with TiB₂ composites were successfully fabricated using powder metallurgy and evaluation of physical and mechanical behaviour are done. The following conclusion have been drawn.

1. An improved hardness of Cu 95% + TiB₂ 5% composites due to high load bearing capacity was offered by reinforcement particles.
2. The Cu 97%+TiB₂ 3% composite shows a higher compression strength than alloy and another composites. The improvement in composite due to dislocation strengthening in the matrix.

5. REFERENCES

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