



Experimental Investigation of Mechanical Behaviour of Copper Matrix Composite Material

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Abstract

This research paper describes the enhancement of mechanical behaviour of the Copper (Cu) matrix composite by reinforcing Tungsten oxide (WO_3). 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 WO_3 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 WO_3 particles. It can be understood that the WO_3 particles occupy substitutional type reinforcement in the Cu matrix.

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

1.INTRODUCTION

The composite material is made of a mixture of two or more distinctly different insoluble materials. The main objective of adding reinforcement was to improve the desired properties of the base material based on suitable applications. Copper (Cu), magnesium, titanium and aluminum-based composites are commercially and widely used composite materials. Among which, Cu is considered to be one of the most dominant nonferrous materials that find extensive applications in cooling system applications, electrical contacts, heat sink applications, antifriction, antiwear and semiconductor devices. The addition of single reinforcement especially Cu-W composite materials finds application in welding electrodes, high voltage electric contacts, and micro electronic materials. Similar kinds of other popular reinforcing materials such as B4C, Ti & TiO_2 , WC, TiC etc, promised to increase the thermal conductivity, electrical conductivity, hardness, and wear resistance. At present, industry demands to reduce the weight and cost of the material without sacrificing its mechanical, electrical, tribological and thermal properties. The demand even extends up to finding the machining characteristic of the composite material and cost of fabrication etc. One factor which reduces the cost of fabrication is to reinforce the low cost material. Some of the low density reinforcement materials which are widely used in copper are MoS₂, SiC, Al₂O₃, graphite, and Fly Ash (FA). The addition of low density material has certain advantages and disadvantages. For example, MoS₂ is one of the solid lubricants mainly added with Cu to improve the machinability of the material but it undergoes reaction with the base material and also acts like a poor lubricant. Similarly, the addition of Al₂O₃ increases the hardness but reduces the compressive strength of the material due to the localized softening of the material. Very few works of literature are available for using WO_3 as reinforcement. Among the various choice of second reinforcement materials such as Ti, TiO_2 , B4C, WO_3 , etc, WO_3 is considered to be one of the most attractive materials as it finds much application in electronic, aerospace and defence field. Hence W was chosen as secondary reinforcement material for this study. The method of fabrication of the hybrid composite material (Cu— WO_3) is another important parameter that highly influences the material properties. The most common techniques used are solid phase processing and liquid phase processing. Though liquid phase processing (casting) is suitable for mass production, it has certain disadvantages such as the non-uniform distribution of reinforcements, the reaction of reinforcement with the matrix phase, the formation of oxides and the segregation of reinforcement etc. In this study, the Powder metallurgy process was used for the fabrication of preforms and uniform distribution of reinforcement was achieved. Based on the literature review and demand to reduce the weight and cost of the composite material with improved strength, it is necessary to find the mechanical behaviour of Cu- WO_3 composite material. Hence the present study aims to fabricate Cu-- WO_3 composite material with a weight percentage of Cu-97% -3% WO_3 , Cu-96% -4% WO_3 , Cu-95% -5% WO_3 and pure Cu through powder metallurgy process. The mechanical behaviour was studied using the Vickers hardness and compressive test

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 Oxygen Free Copper

2.2 Tungsten Oxide(WO₃)

Tungsten(VI) oxide, also known as tungsten trioxide is a chemical compound of oxygen and the transition metal tungsten, with formula WO₃. The compound is also called tungstic anhydride, reflecting its relation to tungstic acid H₂WO₄. It is a light yellow crystalline solid. Tungsten trioxide is a starting material for the synthesis of tungstates. Barium tungstate BaWO₄ is used as a x-ray screen phosphors. Alkali metal tungstates, such as lithium tungstate Li₂WO₄ and Cesium tungstate Cs₂WO₄, give dense solutions that can be used to separate minerals. The applications includes Fireproofing fabrics, Gas and humidity sensors, Ceramic glazes where it gives a rich yellow color. Electrochromic glass, such as in smart windows, whose transparency can be changed by an applied voltage. Photocatalytic water splitting. Substrate for surface-enhanced Raman spectroscopy replacing noble metals.

Element	Titanium	Boron
Content %	79.29	20.71

Table 1: Chemical Composition of tungsten oxide(WO₃)

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%	58	55	52	55
2	Cu 97%+ WO ₃ 3%	74	75	72	73.7
3	Cu 96%+ WO ₃ 4%	97	95	99	97
4	Cu 95%+ WO ₃ 5%	91	89	92	91

Table 3.1.1 Hardness Results for different % of WO₃

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/5wt.%WO₃ composites 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%+ WO₃3%)

Test Parameters	Observed Values
Compression Strength(Mpa)	112
Compression Load(kN)	14.22

Compression Test: (Cu 96%+ WO₃4%)

Test Parameters	Observed Values
Compression Strength(Mpa)	112
Compression Load(kN)	8.910

Compression Test: (Cu 95%+ WO₃5%)

Test Parameters	Observed Values
Compression Strength(Mpa)	151
Compression Load(kN)	8.910

4.CONCLUSION

Copper matrix composites reinforced with WO₃ were prepared via powder metallurgy process. The impact of WO₃ 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 WO₃ 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% + WO₃ 4% composites due to high load bearing capacity was offered by reinforcement particles.
2. The Cu97%+ WO₃5% 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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