Study of Mechanical Properties of Sintered CUZN30 (Brass) - MWCNT Composite Fabricated by Powder Metallurgy.

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Abstract— The number of engineering application in industry demands need light weight, good mechanical properties of material such as aerospace, automotive industry. Day by day selection of material with good mechanical property is the pin point for material selection, hence because it's high stiffness CNT are considered for widely used reinforcement of material in metal matrix Composite. These work summaries the research work carried out in the field of carbon nanotube (CNT) metal reinforcement for composite material. However, CNT-reinforced CuZn30 (Brass) has received the least attention, so that this work also explore more data regarding CNT reinforced CuZn30 (Brass). The main objective of this project is to fabricate and study the mechanical as well as Tribological properties of CuZn30-MWCNT composite. Multiwall carbon nanotubes (MWCNTs) reinforced CuZn30 Nano composites are fabricated by mechanical alloying and powder metallurgy technique. The reinforcement material MWCNTs are blended in three weight fractions (0.33%, 0.66%, and 0.99%) with the matrix material CuZn30 (Cu-70%, Zn-30%) and blended through mechanical alloying using a high energy planetary ball mill. Specimens of CuZn30 and CuZn30-MWCNT composites are fabricated through powder metallurgy technique. After fabrication of CuZn30-MWCNT it is sintered to arranged CNT in unidirectional. The microstructure, density, hardness, porosity, and wear properties of CuZn30 and CuZn30-MWCNT Nano composites are characterized and compared with pure CuZn30 composite for the effect of addition of MWCNT.

Keywords:-CuZn30 (Brass), MWCNT, PM, Mechanical Properties…

I. Introduction

Metal matrix composites (MMCs) reinforced with nano-particles, also called Metal Matrix nano-Composites (MMnCs), are being investigated worldwide in recent years, owing to their promising properties suitable for a large number of functional and structural applications. The reduced size of the reinforcement phase down to the nano-scale is such that interaction of particles with dislocations becomes of significant importance and, when added to other strengthening effects typically found in conventional MMCs, results in a remarkable improvement of mechanical properties. The main issue to be faced in the production of MMnCs is the low wettability of ceramic nano-particles with the molten metal matrix, which do not allow the production of MMnCs by conventional casting processes. Small powder aggregates are in fact prone to form clusters, losing their capability to be homogeneously dispersed throughout the matrix for an optimal exploitation of the strengthening potential. For this reason, several alternative methods have been proposed in order to overcome this problem. In the literature, different kinds of matrix metals have been coupled with several types of nanometric phases. Ceramic compounds (SiC, Al2O3, etc.), intermetallic materials and carbon allotropes were used to reinforce Al, Mg, Cu and other metals and alloys. Particular importance is assigned to carbon nanotubes (CNT), which are characterized by very high strength, stiffness and electrical conductivity. These properties confer higher mechanical strength while improving electrical and thermal properties of the base material. Moreover, MMnCs revealed to be able to improve other interesting engineering properties, such as damping capacity, wear resistance and creep behavior. This paper is aimed at reviewing the theoretical and experimental background related to bulk MMnCs and the major results achieved in this field. Structural properties and mechanical performance induced by nano-particle and nano-tube addition to base metals will be presented and the state of art of the synthesis methods will be described.

CuZn30 (Brass) have been widely used in tribological engineering parts, sliding bearings and also in electrical and thermal devices. These composites have been characterized for their high mechanical strength, friction, electrical resistivity and thermal conductivity. Diverse efforts have been CuZn30 (Brass) focusing on improving their mechanical, tribological properties useful for specific applications. To overcome this problem, many studies have been carried out on incorporation of various additives in the composites in order to increase the interface strength and improve the mechanical, electrical and thermal properties of the composites for various applications. Various methods have been adopted to prepare Cu composites of excellent mechanical and physical properties, such as powder metallurgy, impregnation, hot isostatic pressing and chemical reduction method. Out of these methods, powder metallurgical route has shown many advantages over these methods for the possibility of obtaining good quality composites with low cost. Nowadays, carbon nanotubes (CNT) have received significant attention as a reinforcement material in the polymer, metal and ceramic matrix materials for the development of high quality composites, which is due to their excellent mechanical and tribological properties. Therefore, in present research work, we have studied influence of multiwall carbon nanotubes (MWCNT) reinforced in CuZn30 (Brass) and developed CuZn30 (Brass)/ CNT composites through powder metallurgy technique without using any extra binder to produce high performance composites. CuZn30 (Brass)/ CNT composites have been investigated for structural, mechanical, tribological properties.

Composite materials are becoming necessary for modern technologies in order to improve both mechanical and physical properties of materials. Composite are a physical mixture in macroscopic scale which is made of two or more materials. The ingredients preserve their physical and chemical properties; however the mixture provides even better properties than its constituents. Metal-matrix composites (MMC) have widely developed in recent years; e.g. aluminium-matrix composites which caused huge efficiency and diversity in the industry. Since 1991 that it was discovered by Ijima, CNT is widely used and investigated in different materials. Carbon nanotube is accounted as reinforcement due to its great physical and mechanical properties. Due to high strength, elastic modulus, flexibility, conductivity and other properties, CNT is widely used and studied as reinforcement in composite materials. Copper-matrix composites also show low thermal expansion coefficient, high stiffness, electrical and thermal conductivity and strength and proper wear resistance. Copper- or graphite-matrix composite combine diverse properties; they are efficient at high temperatures and also show high electrical and thermal conductivity. Hence, copper and carbon nanotube composition may produce unique properties such as high and improved mechanical strength and thermal and electrical conductivity, low thermal expansion coefficient and enhanced hardness and wear resistance. Carbon nanotubes as reinforcement would cause increase of strength and physical and mechanical properties improvement in metal- or ceramic-matrix composites. It may be regarded to the remarkable mechanical and physical properties of carbon nanotubes. Copper and CNT Nano composites (Cu-CNT) have been manufactured by various procedures such as mechanical milling method, chemical and molecular method (wet chemistry), electrolytic method, molecular- mechanical milling method and some other procedures. The most significant issue in processing these Nano composites is distribution of carbon nanotubes in copper matrix. The carbon nanotubes distribution is important so if it is problematic and nanotubes remained in cluster forms or agglomerated, composite properties would deteriorate. Powder metallurgy is used to produce metal-matrix composites reinforced with discontinuous fibres, particles and whiskers. In mechanical milling method, presence of initial particles with grain size of 3-45 microns in the mixture of copper powder and carbon nanotubes leads to improvement of mechanical properties for addition of CNT up to 0.5-1 wt. %. The measured sintering temperature for copper-CNT composition in this method is reported between 850 to 950°C. In this research, powder metallurgy was used to produce copper-matrix and CNT compositions. Pure copper powder containing diverse CNT weight percentages (0-3) was ground by planetary mills. Pure copper has a high conductivity but also is soft and limited for some applications; Properties of carbon nanotubes were incentive to use them in the copper matrix composites as reinforced. Goal of this research was to study the effect of CNT on mechanical properties of copper-matrix composites .

Copper Alloy:-

CuZn30 (Brass):-

Carbon nanotubes:-

Carbon Nanotube (CNT) is tubular form of carbon with diameter as small as 1nm and length of few nm to microns. CNT is configurationally equivalent to a two dimensional grapheme sheet rolled into a tube. Its Young's modulus is over 1 TPa and the tensile strength is an estimated 200 GPa. Depending on the atomic arrangement of the carbon atoms making up the nanotube (chirality), the electronic properties can be metallic or semiconducting in nature, making them widely used in several applications due to their unique electrical, mechanical, optical, thermal and other properties. The application of CNTs is usually given by the CNTs structure according to Dresselhaus MS. et al. (1995) & Jan Prasek (2011) (number of walls, diameter, length, chiral angle, etc.), which gives them the specific properties. The possible applications of CNTs include conductive films, solar cells, fuel cells, super capacitors, transistors, memories, displays, separation membranes and filters, purification systems, sensors, clothes etc. [20]. Classification:-

On the basis of structure carbon nanotubes are of five types:

- Single Walled Nano Tube: Most single-walled nanotubes (SWNT) have a diameter of close to1 nanometer, with a tube length that can be several thousand times the diameter.
- Multi Walled Nano Tube: Multi-walled nanotubes (MWNT) consist of multiple layers of graphite rolled on them to form a tube shape.
- Polymerized SWNT: These are the solid-state manifestation of fullerenes and related compounds and materials. Many single walled nanotubes intertwine to form polymerized SWNTs, which are comparable to diamond in terms of hardness.
- Nanotorus: A nanotorus is a theoretically described carbon nanotube bent into a torus (donut shape). Nanotori have many unique properties, such as magnetic moments 1000 times larger than previously expected for certain specific radii.
- Nanobuds: Carbon Nanobuds are a newly discovered material combining two previously discovered allotropes of carbon: carbon nanotubes and fullerenes. In this new material fullerene-like ―buds‖ are covalently bonded to the outer sidewalls of the underlying carbon nanotube.

Fig.- SWCNT

Fig.- MWCNT

II. Problem Statement

From the literature review and identified gap it is clear that as per my observation no author have discussed about the improvement in property of material with increase in the percentage CNT. Hence it is decided to fabricate the material with variation in percentage of CNT reinforced with CuZn30 (Brass) and to study mechanical and Wear Properties of Composite. Find out the suitability of material for bearing material

III. Objective

1) The main objective of this research is to study CuZn30 (Brass) Nano composites reinforced with higher weight fraction of MWCNTs through mechanical alloying and powder metallurgy process to enhance the mechanical properties.

2) Three weight fractions of MWCNTs 0.33%, 0.66%, and 0.99% are added to the matrix of CuZn30 (Brass) and blended through high energy planetary ball mill to improve the homogeneity of the reinforcement material and to reduce the agglomeration.

3) The specimens of CuZn30 (Brass) and CuZn30 (Brass) -MWCNT composites prepared through powder metallurgy and Sintering will be characterized for the microstructure and mechanical, tribological properties and compared for the effect of increasing weight fraction of MWCNTs.

IV. SCOPE

Scope of this project is to decrease wear rate of CuZn30 (Brass) by adding MWCNTs. The density of the fabricated composite will be decreasing due to addition of light weight MWCNTs. The hardness and wear tests have revealed Enhanced mechanical properties of CuZn30 (Brass) -CNT composites due to the effect of mechanical alloying through ball milling. Mechanical alloying through high energy ball milling helps to improve homogeneous mixing and reduces the deterioration of MWCNTs within the CuZn30 (Brass) matrix.In automobile industries are used bearings for power transmission therefore wear is occur and it is directly related performance of vehicle. We are manufacturing the reducing wear rate material so this material is used in automobile industry, power plant, aerospace, sport equipment.

V. METHADOLOGY

Composite Material Specification

CuZn30 (Brass)

CuZn30 (Brass) is Copper based alloy in that Copper is base metal matrix composite

Table -specification of CuZn30 (Brass)

Sr. no	Material	Purity	% of weight
1	Cu	99%	70
2	Zn	99%	30

Specifications of MWCNT

The specification of MWCNT shown in table 3.2. The reinforcement material MWCNT with three weight fractions of 0.33%, 0.66%, and 0.99% is add to the matrix of CuZn30 (Brass).

Table -Specifications of MWCNT

Material	Diameter Nm	Length m	Purity	Amorphous carbon	Density g/cm^3	Surface area M^2/g
MWCNT	20-30	3-8	>95%	<3%	2.0	90–350

Powder metallurgy

Powder metallurgy is the process of blending fine powdered materials, pressing them into a desired shape or form (compacting), and then heating the compressed material in a controlled atmosphere to bond the material (sintering). The powder metallurgy process generally consists of four basic steps: powder manufacture, powder blending,compacting, and sintering. Compacting is generally performed at room temperature, and the elevated-temperature process of sintering is usually conducted at atmospheric pressure. The use of powder metal technology bypasses the need to manufacture the resulting products by metal removal processes.

Blending

Mechanical alloying (MA) is a high energy ball milling process by which constituent powders are repeatedly deformed, fractured and welded by grinding media to form a homogeneous alloyed microstructure or uniformly dispersed particulates in a matrix (Suryanarayana, 2001). The main objectives of the milling process is to reduce the particle size (breaking down the material), mixing, blending and particle shaping. The process requires at least one fairly ductile metal (e.g. Cu) to act as a host or binder. The major process in MA for producing quality powders of alloys and compounds with well-controlled microstructure and morphology due to the repeated welding, fracture, and re-welding of the reactant mixed powders (Benjamin, 1992). It is critical to establish a balance between fracturing and cold welding in order to mechanically alloy successfully.

Uniaxial compacting

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.

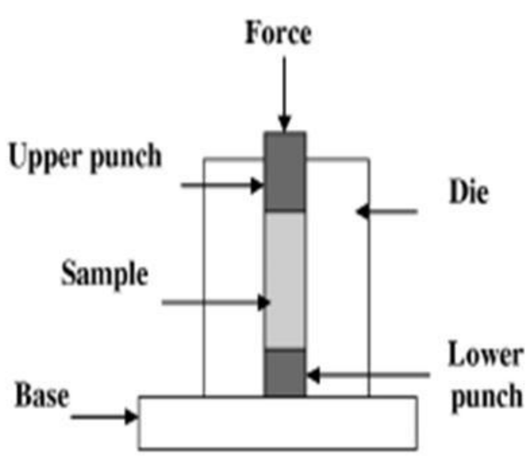

Fig -Compacting processes

Various homogenized powder mixtures of CuZn30 (Brass) and MWCNTs are then compacted at a pressure of 728 M Pa to form billets of 23 mm diameter and 40 mm height. Each billet is formed 150 gram of mixtures powder. The compacted sample is shown in fig..

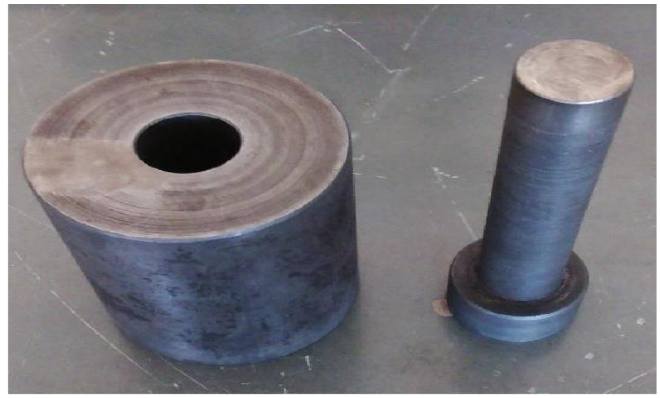

Fig -Die –punch set-up

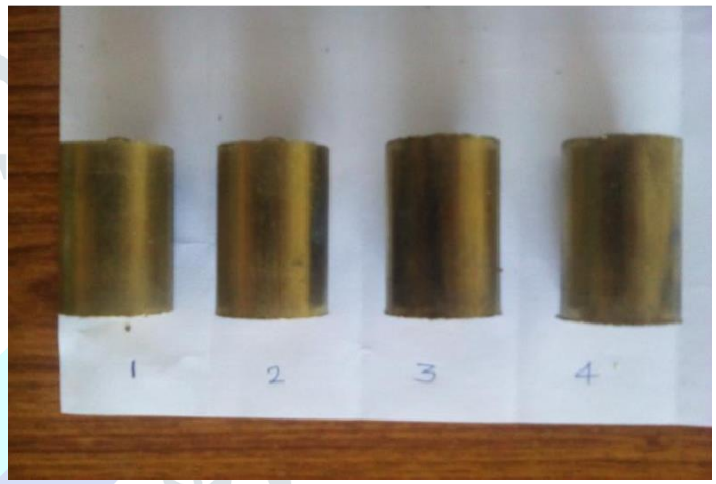

Fig -Compacted sample of CuZn30 (Brass)-MWCNT

1. CuZn30 + 0% CNT, 2. CuZn30 + 0.33% CNT, 3.CuZn30 + 0.66% CNT, 4. CuZn30 + 0.99% CNT

Sintering

Sintering is the process of forming a solid mass of material by heat without melting it to the point of liquefaction. Form of a powder and placing it into a mold or die. Once compacted into the mold the material is placed under a high heat for a long period of time. Under heat, bonding takes place between the Sintering can be considered to proceed in three stages. During the first, neck growth proceeds rapidly but powder particles remain discrete. During the second, most densification occurs, the structure recrystallizes and particles diffuse into each other. During the third, isolated pores tend to become spheroidal and densification continues at a much lower rate. The words Solid State in Solid State Sintering simply refer to the state the material is in when it bonds, solid meaning the material is not turned molten to bond together as alloys are formed.

In this project work the compacted billets are then sintered in a tube furnace at 900°C without argon gas as protective atmosphere for 2 hours. The sintered sample is shown in fig.

VI .RESULTS & DISCUSSION

Density

It is observed that the density of the Nano composites decreases with increasing weight percentages of MWCNTs. According to observation distribution of dislocations within the matrix of the composites would not be uniform and there will be higher density near the reinforcing particles. This is calculated by theoretically.

Table -Theoretical density of CuZn30 (Brass) -MWCNT composite

Composite	Density (g/cm^3)
CuZn30 (Brass)	7.6395
CuZn30 (Brass)-0.33%MWCNT	7.3156
CuZn30 (Brass)-0.66%MWCNT	7.2795
CuZn30 (Brass)-0.99%MWCNT	7.0718

The reason for the decrease in the density is due to the addition of light weight and high volume MWCNTs compared to the matrix material.

The experimental green density can be find out by with Archimedes's principle. The experimental density values are given in table .

Table -Experimental Green density of CuZn30 (Brass) -MWCNT composite

Composite	Wt. in air (gm.)	Wt. in liquid(gm.)	Density (g/cm^3)
CuZn30 (Brass)	149.9	130.2	7.6010
CuZn30 (Brass)-0.33%MWCNT	149.9	129.9	7.5196
CuZn30 (Brass)-0.66%MWCNT	149.9	130.0	7.5246
CuZn30 (Brass)-0.99%MWCNT	149.8	129.6	7.4079

The reason for the decrease in the density is due to the addition of light weight and high volume MWCNTs compared to the matrix material.

The experimental Sintered density can be find out by with Archimedes's principle. The experimental density values are given in table

Table -Experimental Sintered density of CuZn30 (Brass) -MWCNT composite

Composite	Wt in air(gm.)	Wt in liquid(gm.)	Density (g/cm^3)
CuZn30 (Brass)	150.0	130.3	7.6061
CuZn30 (Brass)-0.33%MWCNT	149.9	129.8	7.4498
CuZn30 (Brass)-0.66%MWCNT	150.1	129.4	7.2435
CuZn30 (Brass)-0.99%MWCNT	150.0	128.9	7.0442

Table - Density Variation of CuZn30 (Brass) -MWCNT composite

Composite	Theoretical Density (g/cm^3)	Green Density (g/cm^3)	Sintered Density (g/cm^3)
CuZn30 (Brass)	7.6395	7.6010	7.6061
CuZn30 (Brass)-0.33%MWCNT	7.3156	7.5196	7.4498
CuZn30 (Brass)-0.66%MWCNT	7.2795	7.5246	7.2435
CuZn30 (Brass)-0.99%MWCNT	7.0718	7.4079	7.0442

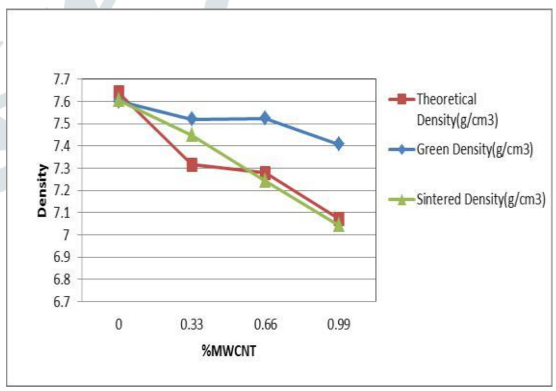

Fig -Graph of Density Vs % of MWCNT

The comparison between the green and sintered densities is represented in Fig. 4.4 Results showed that there are slight different of the density between the theoretical and the sintered products because of some reasons:

- Theoretical density is based on the exact density of CuZn30 and MWCNT.

- The actual density of CuZn30 might be difference due to the production route of the CuZn30.

Porosity

Porosity can be calculated from theoretical density and experimental density.

Table -Porosity of samples

Composite	Porosity %
CuZn30 (Brass)	0.43
CuZn30 (Brass)-0.33%MWCNT	0.46
CuZn30 (Brass)-0.66%MWCNT	0.49
CuZn30 (Brass)-0.99%MWCNT	0.52

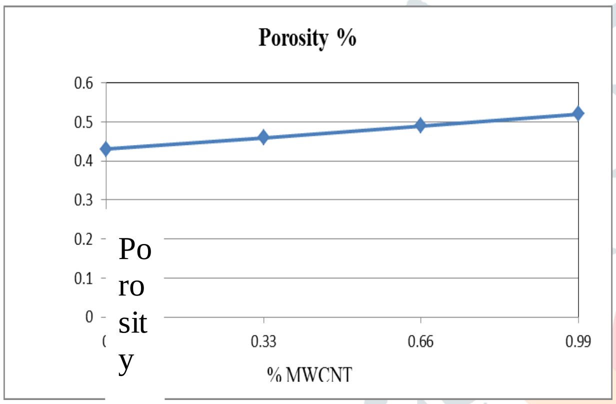

Fig -Graph of Porosity Vs % of MWCNT

Porosity can be calculated from theoretical density and experimental density. The Porosity level increases in all composites with addition of 0.99wt% CNTs. The porosity in all the nano composites is higher than that in CuZn30. The reason behind the increase in porosity is due to the clustering effect of CNTs. When more volume of CNTs added in to the CuZn30 matrix, the work of force decreases and leads to a possible reason for the increase in clustering effect which will inevitably lead to increase in porosity and decrease in the density.

Hardness

From the table .it is observed that hardness of CuZn30 (Brass) increases as percentage of MWCNT increases. This increase in hardness is due to increase in percentage of carbon.

Table -Hardness in HRE

Composite	Centre	Edge	Edge	Avg.
CuZn30 (Brass)	84	70	74	76
CuZn30 (Brass)-0.33%MWCNT	87	78	82	82
CuZn30 (Brass)-0.66%MWCNT	89	80	85	84
CuZn30 (Brass)-0.99%MWCNT	91	85	88	88

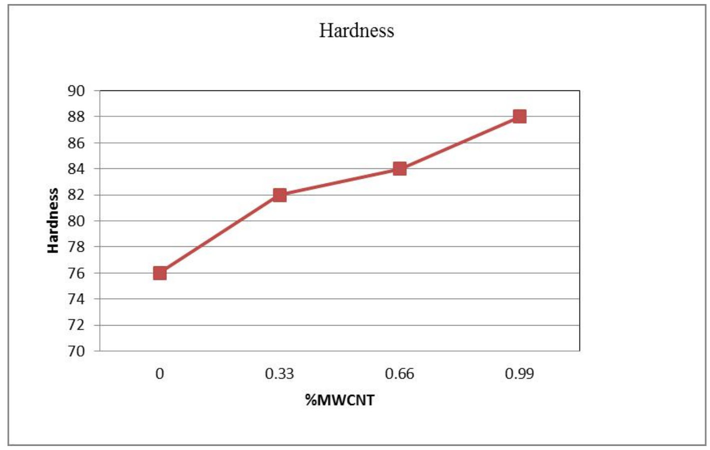

Fig -Graph of Hardness Vs % of MWCNT

From this it is observed that hardness of CuZn30 (Brass) increases as percentage of MWCNT increases. This increase in hardness is due to increase in percentage of carbon.

VII.CONCLUSION

- Powder metallurgy process followed by mechanical alloying is successfully applied to synthesize CuZn30 (Brass)-MWCNT Nano composites.
- Mechanical alloying through high energy ball milling helps to improve homogeneous mixing and reduces the deterioration of MWCNTs within the CuZn30 (Brass).
- The micro hardness have revealed enhanced mechanical properties of CuZn30 (Brass)-CNT composites due to the effect of mechanical alloying through ball milling and Sintering.
- In comparative study of CuZn30 (Brass) and CuZn30 (Brass)-MWCNT. It was observer that wear resistance of CuZn30 (Brass) enhanced with reinforcement of MWCNT.
- Microstructural examination of the as sintered CuZn30 (Brass)-MWCNT composite shows absence of blow holes.

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