

Synthesis and Fabrication Cu/CNT Composite by Stir Casting and Powder Metallurgy Process



#Mr. S. A. Deshmukh , #2 Prof. J. Jayakumar

¹116santosh@gmail.com

²j_j_kumar@rediffmail.com

^{#12}Department of Mechanical Engg, DPVVP COE, Viratghat, Savitribai Phule Pune University

ABSTRACT

The number of engineering application in industry demands need best mechanical properties of material such as aerospace, automotive industry, or wing of aero planes, propeller and manufacturing turbine blade. The reinforcement of light weight Cu alloy with short fibre, pallet particles of ceramics, silicon carbide or alumina are measurly used in metal matrix composites to enhance light weight and mechanical property of MMC used. 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 used reinforcement of material in metal matrix Composite. This work concludes the research work carried out in the field of carbon nano tube (CNT) metal reinforcement for composite material. However, Cu-reinforced CNT has received the least attention; so that this work also explores more data regarding CNT reinforced Cu. The work expects these composite are being projected for use in structural application, bearings, light weight application etc. Processing technique used for synthesis of composite has been critically revised from other literature survey and trying to minimize the gap of processing technique. This work also concludes the CNT dispersion and its quantification in Cu. CNT reinforced Cu as kept as a functional material will be processed by Powder Metallurgy as well as Stir Casting Method.

Keywords— Cu, CNT, Powder Metallurgy, Stir Casting.

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I. INTRODUCTION

Composite materials are combination of different constituent materials which can lead to the desired combination of low weight, stiffness and strength. At present, knowledge has advanced to a level that materials can be modified to exhibit certain required properties. At the same time, the fact that these materials are composed of different constituents makes their mechanical behavior complex. Moreover, density and homogeneity of composites are very important factors in engineering applications because in homogeneity and residual pores are harmful to mechanical and physical properties. Great interest has recently been developed in the area of nanostructures carbon materials and it is becoming of considerable commercial importance. Besides, with much interest growing rapidly over the decade, the discovery of carbon nanotubes (CNTs)

at the beginning of the last decade has been the focus of the growing attention of scientific communities, due to their vast interesting properties as well as their large potential for practical applications. Consequently, based on their unique size and structural diversities, CNTs have attractive properties with their tensile strength to be at least 10 times higher, and their weight is less than half that of conventional carbon fibers.

Particle reinforced metal matrix composites (MMCs) are now recognized as important structural materials for application in aerospace and automotive parts. The reinforcement of light weight Cu alloys with short fibers, platelets and particle of ceramics such as silicon carbide or alumina results in composite of high specific strength and stiffness suitable for engineering applications like aerospace and automotive. There are several routes by

which the reinforcement may be introduced in the matrix. The plunger technique is an effective method for preparation of light weight MMC. The microstructure and property of resulting composite material depends on production method, type and amount of reinforcing particulates. In order to get desirable properties in composites, factors such as nature and choice of the metal matrix, the kind of dispersed particulates making the composite and the technique involved in the composite production, are important and must be standardized. Most convenient metal matrices used are of light weight metals like Cu, magnesium and their alloys. Generally ceramic materials with moderate to high strength and high modulus are used as reinforcement particles. Most widely used particulate reinforcements are SiC, Al₂O₃, fly ash, TiB₂, and B₄C₃. Though varieties of other materials have also been tried during the past years, SiC is easily available and economic. The processing technique for preparation of MMC includes solid state processing and liquid metal processing. Two liquid metal processing involve various types of solid particulate incorporation methods such as pressure infiltration, centrifugal casting, ultrasonic infiltration, spray casting and stir casting processes Good wetting between solid ceramic particles and liquid matrix metal is essential to get uniform dispersion and satisfactory properties in MMC. Alloying elements such as magnesium, lithium, calcium or zirconium are added for inducing wettability. Magnesium in addition to improving the wettability also increases the strength by solution strengthening Cu matrix metal matrix composites CMMC.

II. LITERATURE REVIEW

1. Saeed Hariri (2014): Here author works on investigation on production and mechanical characteristics of copper-matrix Nano-composites strengthened with carbon nanotubes through metallurgy of powder-Demonstrating unequal and conspicuous characteristics since invention, carbon nanotubes had been investigated extensively in compound or composite materials. Due to the high adaptable modulus and reinforcement, notable physical and chemical properties; CNT was found to be employed as strength in metal-matrix and porcelain-matrix materials. In the present paper, copper-matrix Nano composites strengthened with CNT was processed with the help of powder metallurgy. Firstly, the impurity free copper powder with different percentages of CNT weight (0-3) was milled mechanically.

2. Riccardo Casati and Maurizio Vedani (2014): Here author works on Metal Matrix Composites Reinforced by Nano-Particles: Metal matrix composites reinforced by nano-particles are very promising materials, suitable for a large number of applications. These composites consist of a metal matrix filled with nano-particles featuring physical and mechanical properties very different from those of the matrix. The nano-particles can improve the base material in terms of wear resistance, damping properties and mechanical strength. Different kinds of metals, predominantly Al, Mg and Cu, have been employed for the production of composites reinforced by nano-ceramic particles such as carbides, nitrides, oxides as well as carbon nanotubes. 3. S. Kumari, A. Kumar & P. R. Sengupta (2014): Here author works on Multiwalled carbon nanotubes (MWCNT)- reinforced carbon/copper (C/Cu)

composites were developed by powder metallurgy technique and mixed powders of C and Cu were consolidated into plates without using any extra binder followed by sintering at 1000°C in inert atmosphere.

4. B. P. Samal, S. C. Panigrahi & B. Sarangi (2013): Here author works on Metal Matrix Composites (MMCs) are highly attractive for large range of hi-tech engineering applications because of their useful properties. However the methods used to produce these composites are constantly evolving particularly in getting rid of non-uniform distribution of the reinforcement. Stir casting is the most commonly used method for production of particulate reinforced cast metal matrix composites. A recently developed modification of stir casting has been used in the present investigation to produce aluminum-magnesium matrix composites reinforced with silicon carbide.

5. Manjunatha & Dinesh (2013): Here author works on Powder metallurgy techniques have emerged as promising routes for the fabrication of carbon nanotube (CNT) reinforced metal matrix composites. In this present work has been made to investigate the mechanical properties of the fabricated Composites. Cu alloys as matrix and Multiwall Carbon Nanotube (MWCNT) as reinforcement (0, 0.5, 1.0, 1.5, 2, 2.5 & 3 weight percentage) have been fabricated by powder metallurgy process. Cu powder (200 mesh) and multiwalled carbon nanotubes (Nanoshell, USA) were procured from different sources available in the market. The two materials were properly mixed for different composition by using ball mill, to mix uniformly CNT's with Cu powder. Compacting die was used to compact the powder by using 40 Ton capacity hydraulic press, after compacting the powder in to solid billet. A low cost sintering furnace was designed and fabricated for current research work.

6. Maneet Lal, S. K. Singhal, Indu Sharma & R. B. Mathur (2013): Here author works on Copper has a wide range of applications due to its excellent properties (high thermal and electrical conductivity). Carbon nanotubes (CNTs) are widely used as a reinforcing material due to their superior properties. Copper/Carbon nanotube (Cu/CNTs) composites show enhanced mechanical, electrical and thermal properties as compared to pure Cu and Cu composites. Hence, Cu/CNTs composites have tremendous applications. Cu/CNTs are being developed for use as antifungal and antimicrobial agents, which can lead to their further use in biomedical devices and implant materials. The versatility of this material is such that Cu/CNTs are being developed for use in ultra-large scale integrated circuits for use in the latest integrated circuits and semiconductor chips.

7. Shubham Mathur, Alok Barnawal (2013): Here author works on In the present study a modest attempt has been made to develop aluminum based silicon carbide particulate Metal Matrix Composites (MMC) with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous dispersion of ceramic material. Desired improvements in properties including specific strength, hardness and impact can be achieved by intelligently selecting the reinforcement materials, their size, and shape and volume fraction. It has been observed that melting and pouring conditions have directly or indirectly effect on mechanical properties of cast materials as hardness, percentage elongation, percentage reduction in diameter, toughness and so on. The knowledge of melting

temperature of metals and alloys is necessary to estimate their corresponding pouring temperature.

8. Ajay Singh, Love Kumar & Mohit Chaudhary (2013): Here author works on 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 aluminum based metal matrix composite materials is to combine the desirable attributes of metals and Ceramics.

9. P. Jenei, J. Gubicza & E.Y. Yoon (2013): Here author works on The thermal stability of ultrafine-grained (UFG) microstructures in pure copper samples and copper-carbon nanotube (CNT) composites processed by High Pressure Torsion (HPT) was compared. The UFG microstructure in the sample consolidated from pure Cu powder exhibited better stability than that developed in a casted Cu specimen. The addition of CNTs to the Cu powder further increased the stability of the UFG microstructure in the consolidated Cu matrix by hindering recrystallization, however it also yielded a growing porosity and cracking during annealing. It was shown that the former effect was stronger than the latter one, therefore the addition of CNTs to Cu has an overall benefit to the hardness in the temperature range between 300 and 1000 K. A good agreement between the released heat measured during annealing and the calculated stored energy was found for all samples.

10. Ping-Chi Tsai & Yeau-Ren Jeng (2013): Here author works on Carbon nanotube reinforced copper matrix (CNT/Cu) composites with high strength and good damping have been developed using acid treatment, sintering processes and consolidation techniques. Strengthening of the composites as a result of nanotube buckling has been demonstrated by experimental Nanoindentation tests and molecular dynamics (MD) simulations.

III. PROCESSES

Many ways have already been studied to manufacture metal matrix nano-composites

1. Powder metallurgy
2. Melting and solidification
3. Thermal spray
4. Electro chemical deposition
5. Other novel techniques.

An overall diagram is showed in Fig. 1 about metal matrix CNTs composites processing^[1].

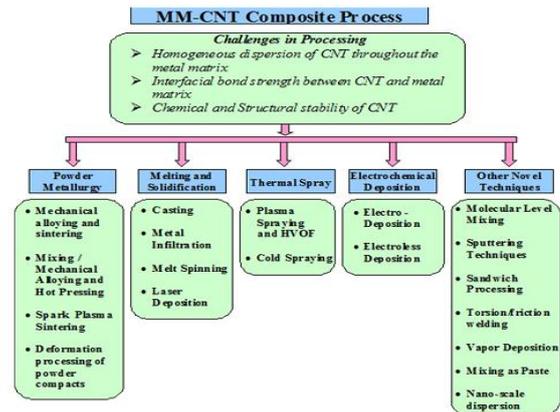


Fig. 1. List of different processing routes for MM-CNT composites

The common challenges in these processing technologies are:

1. CNT homogeneous dispersion in metal matrix^[5]
2. Bond strength at the interface between CNT and metal matrix
3. Stability of CNTs inside metal matrix.

A. Powder metallurgy

a. Mechanical alloying and sintering:

Powder metallurgy technology is widely used, especially in Cu/CNT and Al/CNT composites studies, and a few Sn, Ag, Ni, Ti, Mg matrix base CNT reinforced composites. Some metal matrix nano-composites such as Cu-CNT, Al-CNT, W-Cu and Ag CNT, are prepared with mechanical alloying and sintering^[1].

b. Mixing/mechanical alloying and hot pressing:

Hot pressing is another way researcher to consolidate powder mixtures. Since some studies showed that it is inappropriate to fabricate AL-CNT composites because of CNT clustering electroless coat Ni on CNTs which address dispersing problems, avoid CNTs damage and prepare Ti-CNT composite by hot pressing after 5 hours mechanical mixing, Carreño-Morelli and improved mechanical properties through uniform dispersing of CNTs.

c. Spark plasma sintering:

Spark plasma sintering (SPS) is a process which a pulsed direct current is passed through a die and the powder, producing rapid heating and then enhance the sintering rate greatly[41, 65]. This produced saved time on grain growth to consolidate nano powder. The method is mainly applied to produce Cu-CNT, Al-CNT composites

d. Deformation processing of powder compacts:

To improve CNTs density, distribution and alignment in composites, some researcher tried to deform composites powder compacts. It achieve better alignment in the Al-CNT composites through hot powder compact extrusion at 873K. However, this approach is limited to Cu-CNT and Al-CNT composites.

B. Melting and solidification procedure:

This method is only feasible for low melting point metal, because CNTs may burns under high temperature, or react with metal matrix at the CNT/metal interface. The sub-routine of this method include: casting, metal infiltration, melt spinning and laser deposition. CNT composites by casting, which enhanced hardness and also crystallinity at the same time because of CNT reinforcement. There is also Mg-CNT composites research reported after melting and

casting, due to low melting point of Mg. There is also research reported with infiltration method to disperse CNTs in composite. This process is to disperse CNTs inside porous medium, then infiltrate liquidized metal into porous medium to produce composite structure Mg-CNT and Al-CNT metal matrix composites are reported, the metal matrix is well reinforced, and the hardness and wear resistance of composites are well improved. Metallic glass composites through pouring molten alloy on to a rotating Cu wheel, the alloy is cooled rapidly which generate metallic composite ribbons.^[3]

C. Electrochemical procedure:

Electrochemical procedure is the second popular method after power metallurgy techniques based on the number of metal matrix CNT composites publications, Electro deposition and electro less-deposition are two major sub-index. It is reported that electro deposition is mainly used to prepare Ni-CNT and Cu-CNT matrix composites. Recently, many researches are reported to plating techniques are employed to prepare metal/CNT composites. Fabricated Cu/CNT composites plating by pulse-reverse (PR) electro-deposition method was investigated in order to increase MWCNT content of the composite plating files. To determine the best current in electro-deposition process, electron microscopy and X-ray diffraction were employed to investigate the electro-deposition and dissolution behaviors of composite films. It is reported from the previous studies, that the higher CNT concentration of electrolyte, current density and agitation rate of bath, the higher CNT vol fraction. Electro less deposition, which is the first report of process of depositing a coating with the aid of a chemical reducing agent in solution, and without the application of external electrical power. A few CNT metal matrix composites, Co-CNT, Ni-Fe-P alloy and Ni-Cu-P alloy have been fabricated using this approach.

D. Other processing technique:

Thermal spray is another efficient manner to incorporate CNTs into coatings and bulk components. Better wear resistance and thermal conductivity of the composites in the studies. The major advantage of thermal spraying is to provide large cooling rate, which can reach 108K^{-1} in solidification process.

E. Thermal spray can be classified into three sub-methods:

Flame spraying, cold spraying, high velocity oxy-fuel spraying and plasma spraying Except the method mentioned above, some other methods also reported, which are not widely used, such as Cu-CNT composites with molecular level mixing, sputtering route.

F. Nonlocal theory:

Nonlocal method has been considered as an efficiently computation method to deal with the defects come with incontinuum medium in softening. The material damage behavior under force has been elaborated by many theories, such as coalescence, nucleation and micro-defects. As a certain damage point is attained, damage result to degradation of material elasticity and remarkable overall strength reduction.

G. Stir Casting

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and

may also be processed by conventional Metal forming technologies.

Stir Casting is characterized by the following features:

- Content of dispersed phase is limited (usually not more than 30 vol. %).
- Distribution of dispersed phase throughout the matrix is not perfectly homogeneous:

1. There are local clouds (clusters) of the dispersed particles (fibers);
2. There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase.

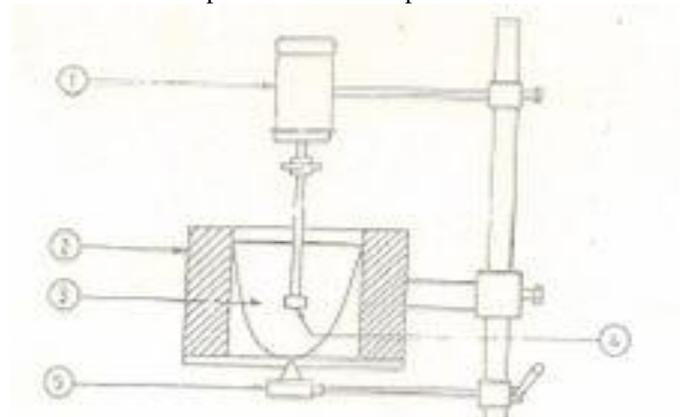


Fig 2. Stir Casting

1-Motor with stirring system, 2-Heating Furnace, 3-Crucible, 4-Stirring blade, 5-Plug.

IV. PROBLEM STATEMENT

A. Gaps Identified From The Literature:

This literature survey does not mention tribological behavior only idea regarding mechanical properties.

Specific application is not mention.

Need for light weight, high strength material for various applications such as racing bikes.

Number of literature survey not deals with CNT reinforcement Metal Matrix Composite (MMC) Method.

Very few works of CNT reinforcement Metal Matrix Composite (MMC) done by Stir Casting.

B. Problem Statement:

The number of engineering application in industry demands need light weight, good mechanical properties of material such as aerospace, automotive industry, or manufacturing turbine blades, propeller and wings of aero planes.

The reinforcement of light weight Cu alloy with short fibre, pallet particles of ceramics, silicon carbide or alumina are measurly used in metal matrix composites to enhance weightless and mechanical property of MMC used.

Day by day selection of material with good mechanical property is the pin point for material selection, hence because its high stiffness CNT are considered for widely used reinforcement of material in metal matrix Composite.

C. Objective of the Project:

- To provide the data regarding CNT reinforcement Metal Matrix Composite method.
- To find mechanical as well as tribological characterization of CNT reinforcement MMC.
- To provide data it will serve as a guide line for future research that one new to be subject.

- To study on CNT reinforced Cu in order to have a clear picture on state of art of powder metallurgy field.
- To study Cu/CNT composite by Stir casting process.
- To discuss CNT behavior in Copper composite for different application.

The scope of the project is the mechanical as well as tribological properties of composites by Powder Metallurgy and Stir Casting method to validate the result using experimental validation.

V. EXPECTED CONCLUSION

Its result analysis conclude that, Observations show that several factors can affect different result greatly. These factors include: CNT volume fraction, harden strain, hardened region volume fraction and meshes size.

Carbon nanotubes reinforced copper matrix composites had been successfully developed through powder metallurgy and characterized their microstructure properties. With about 17 ton load, sufficient enough to produce near full density copper-fiber composite. Sintering temperature at 900°C in the argon gas atmosphere is sufficient to produce good sintered product at the 90 minutes sintered time. The powder particle diffusion bonding can be seen clearly in SEM

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Department of Mechanical Engineering, here knowledge is considered as the liable asset and it is proved that the power of mind is like a ray of sun; and when strenuous they illumine.

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