Influence of Heat Treatment Temperatures on Wear and Hardness Properties of Copper oxide Nanoparticle Reinforced Composites

Manjunatha G*,1, Anil Kumar T*,1

[1] *Dept. of Mechanical Engg. M.S.Ramaiah Institute of Technology, Bangalore, 560054, India.*
gmanjumsrit@gmail.com1, shohniadhi@gmail.com

Abstract - *The study has been conducted to investigate the effect of CuO nanoparticles reinforcement with epoxy matrix. The nanopolymer composites were prepared by solution casting technique by varying 0.5, 1.0, 1.5 and 2.0 wt. % CuO nanoparticles. The nanopolymer composites were heat treated at 50°C, 100°C,150°C .The mechanical properties such as hardness and wear rate were investigated. The significant enhancement in the properties was observed in the nanocomposites. The results showed the improvement in hardness and wear rate at 1wt% of CuO and at heat treated temperature of 100°C as compared to pure epoxy.*

Key Words: *Epoxy, CuO Nanoparticle, solution casting, mechanical properties, heat treated.*

1. INTRODUCTION

Nanocomposites differ from conventional composite materials due to the exceptionally high surface to volume ratio of the reinforcing phase and/or its exceptionally high aspect ratio. The reinforcing material can be made up of particles, sheets or fibres.

Nano copper oxide attracts more and more people's attention, and become one of the most extensively used inorganic materials. The particle size of nanometer copper oxide is between 1-100 nm. Compared with the ordinary copper oxide, Copper oxide Nanoparticle has peculiar physical and chemical properties such as surface effect, superiority of the quantum size effect, volume effect and macroscopic quantum tunneling effect in magnetic, optical absorption, chemical activity and thermal resistance, catalysis, and the melting point[1].

The Epoxy based polymer is mechanically very strong, chemically resistant to degradation of the chemical elements in the solid form and highly adhesive during conversion from liquid to solid. Epoxy consists of resins and a hardener. The resin material is light, colorless and odour free.

Hardeners are dark, heavy and have a slight odour. When these two materials are mixed with, they will chemically bond together and once the chemical reaction is finished, it will form a strong and rigid plastic material. The rate of the reaction can be changed by using different hardeners, which may change the nature of the final product, or by controlling the temperature.

The concept of combining /mixing various materials through synergy is the most successful way to achieve materials with desired properties with great efficiency and cost effectiveness [2].

Dan Guo et al. [3] in this review, the basic physics of the relevant interfacial forces to nanoparticles and the main measuring techniques are briefly introduced first. Then, the theories and important results of the mechanical properties between nanoparticles or the nanoparticles acting on a surface, e.g., hardness, elastic modulus, adhesion and friction, as well as movement laws are surveyed. A brief summary and the future outlook are also given in the final part.

Singh J, Kaur G et al. [4] in this paper, brief review for preparations of copper oxide nanoparticles by the different route are described. They can be reduced to metallic copper when exposed to hydrogen or carbon monoxide under high temperature. Copper oxide nanoparticles are used in wide range of applications such as catalysis, gas sensors, magnetic storage media, batteries, solar energy transformer, semiconductors and field emission have attracted great attention due to its potential application in nano devices such as electronic, optoelectronic and sensing.

Wei Gao et al. [5] the effects of nanosize copper oxide and basic copper carbonate on the physical and mechanical properties of flake boards were investigated according to ASTM Standard D-1037, and the curing process of phenol formaldehyde (PF) resin containing copper compounds was further investigated using dynamic differential scanning calorimetry (DSC). The results showed that nanosize copper oxide had no or slightly beneficial effects on the mechanical properties and dimensional stability of the flake boards.

Sunny AT et al. [6] the mechanical properties including tensile, impact, fracture toughness and surface hardness of epoxy-nCOP nanocomposites were evaluated as a function of nCOP content. The maximum enhancement in strength, modulus, impact strength, fracture toughness and surface hardness of epoxy-nCOP nanocomposites was observed for 5 phr nCOP content. This may be due to the strong interaction between the nCOP and epoxy chains at this composition arising from its fairly uniform dispersion.

Yoshio Kobayashi et al. [7] metal–metal bonding was performed using metallic Cu nanoparticles fabricated from CuO nanoparticles. Colloid solutions of CuO nanoparticles were prepared by the reaction of Cu $(NO_3)_2$ and NaOH in aqueous solution at reaction temperatures (TCuOs) of 20, 40, 60 and 80 °C. CuO single crystallites with a size of ca. 10 nm were produced, and they formed leaf-like aggregates. A maximum shear strength of 39.2 MPa was recorded for a TCuOs of 80 °C.

2. MATERIALS

Copper oxide nanoparticles used in this study was procured from Nano labs, Jharkhand. Copper oxide nanoparticle is a brownish-black powder, 40nm, with 99% purity and 6.3-6.49 g/cm3 density and melting point of 1326 °C. It is soluble in dilute acid, NH_4Cl, $(NH_4)_2CO_3$, potassium cyanide solution, insoluble in water, and it dissolves slowly in alcohols, ammonia solution.

Epoxy resin & Hardener used was Lapox (L-12), Procured from Atul Ltd Gujarat. The Epoxy resin material is light, colorless and odour free. Hardeners are dark, heavy and have a slight odour. When these two materials are mixed with, they will chemically bond together and once the chemical reaction is finished, it will form a strong and rigid plastic.

3. EXPERIMENTAL DETAILS

Step1: The required quantity of CuO nanoparticles and Epoxy are weighed using electronic weigh balance.

Step2: CuO nanoparticles are mixed with acetone using magnetic stirrer for about 15 minutes.

Step3: Epoxy is mixed with copper oxide Nano particles and manually stirred.

Step4: The above mixture is sonicated using ultra sonicator at 150V using ice bath for about 20 minutes.

Step5: Then mixture is heated using infrared lamp to remove the presence of acetone. (Before and after heating the mixture is weighed and weight loss is observed).

Step6: The mixture is cooled in the ice bath till it reaches to room temperature

Step7: The mixture is mixed with hardener as specified by the manufacturer under ice bath using mechanical stirring machine for about 5 minutes.

Step8: The mixture than degassed under vacuum degassing for 5 minutes.

Step9: The Prepared composite mixture are poured into the moulds.

Step10: After solidification the specimens are removed from the moulds and the specimens are heat treated in electric furnace at various temperature.

Step11: The specimens are tested to study the hardness and wear.

3.1 Hardness Test

Hardness test were carried out using Rockwell hardness testing machine. Hardness testing samples were prepared with dimensions as per ASTM D 785 standards. In each case, three samples were tested and the average value was tabulated.

3.2 Wear Test

The wear testing were carried out using pin-on-disc wear testing machine. Wear testing samples were prepared with dimensions as per ASTM G99 standards. In each case, three samples were tested and the average value was tabulated.

4 RESULTS AND DISCUSSIONS

4.1 Hardness Test Results

Hardness test was conducted on CuO nanopolymer composites on 3 specimens of each wt.% of CuO (pure epoxy, 0.5,1.0, 1.5 %) and heat treated at different temperature conditions (50, 100, 150^{0}C).The results of which are shown in the Table 1.

Sl. No	Material	Load in Kg	Pure Epoxy	HRC at 50⁰C	HRC at 100⁰C	HRC at 150⁰C
1	Pure Epoxy	60	50	53	67	56
2	Epoxy+0.5% CuO	60	62	69	89	77
3	Epoxy+1.0% CuO	60	75	82	106	90
4	Epoxy+1.5% CuO	60	66	74	91	82
5	Epoxy+2.0% CuO	60	52	68	97	79

Table 1: Hardness values of CuO/Epoxy nanocomposites at different CuO wt. % and at different heat treatment temperature

Table 1 indicates that the hardness of the pure epoxy specimen is low when compared to the CuO reinforced Epoxy nanocomposites. The hardness number for heat treated at 100⁰C is higher compared to without heat treated and at heat treated 50, and 150⁰C.

4.2 Wear Test Results

Wear test was conducted by keeping load and speed as constant and by varying time. The test was conducted on CuO nanopolymer composites on 3 specimens of each wt.% of CuO (pure epoxy, 0.5,1.0,1.5%) and heat treated at different temperature conditions (50, 100, 150⁰C).The results of which are shown in the chart 1, 2, 3 and 4.

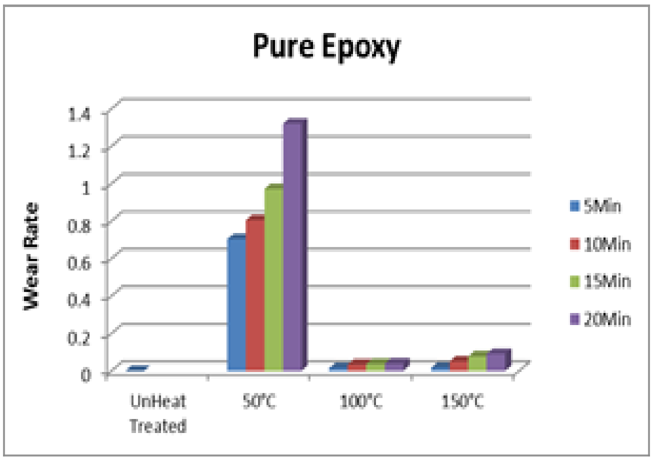

Chart 1 Wear rate v/s temperature for pure epoxy

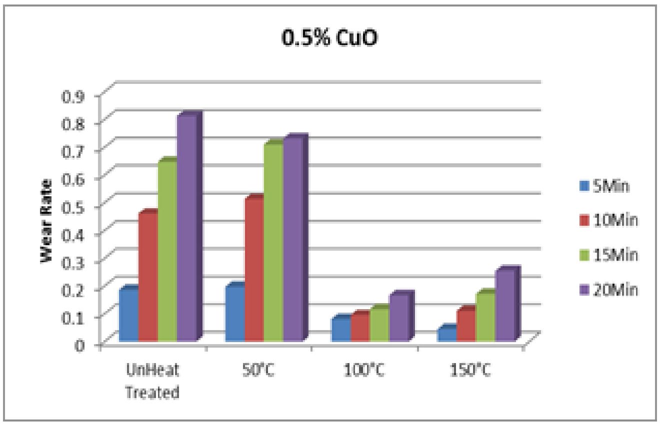

Chart 2 Wear rate v/s temperature for 0.5wt% CuO nanocomposites

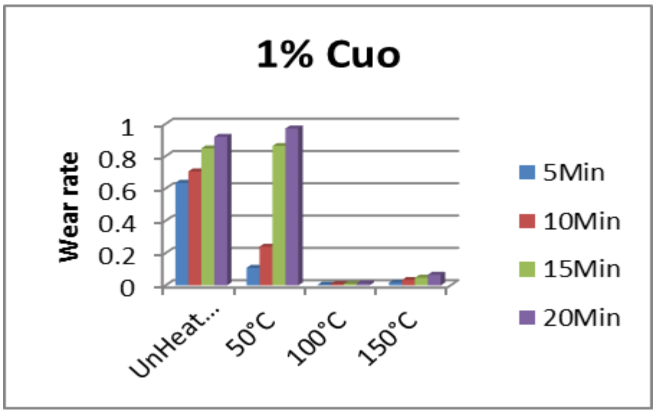

Chart 3 Wear rate v/s temperature for 1.0 wt. % CuO nanocomposites

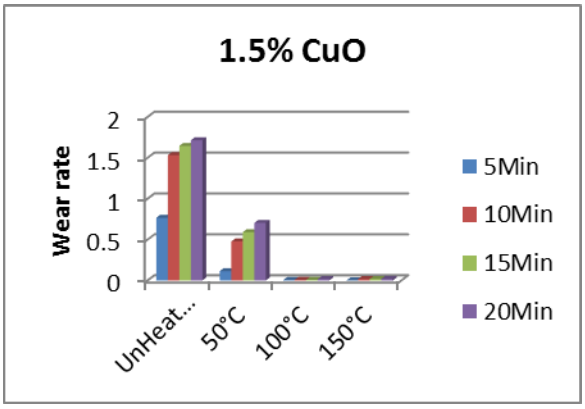

Chart 4 Wear rate v/s temperature for 1.5 wt. % CuO nanocomposites

The chart 1, 2, 3 and 4 shows the wear rate of CuO nanocomposites, without and with heat treated at 50, 100, 150⁰C and for different concentrations of CuO. The wear rate at 1.0% CuO is low compared to pure epoxy. The wear rate for heat treated at 100⁰C is low compared to without and heat treated at 50, and 150^{0}C because due to uniform dispersion of nanoparticle.

5. CONCLUSIONS

[1] Copper oxide nanoparticle reinforced polymer composite were fabricated successfully by Casting Method.

[2] Mechanical properties improved enormously for 1.0% weight fraction of CuO Nanoparticles at 100^{o}C compared to pure epoxy resin base material.

[3] The presence of CuO Nanoparticles showed the improvement in hardness property. Hardness of pure epoxy at 100^{o}C is 67 RHC, but 1.0% CuO filled polymer composite has 106 RHC which is almost near to twice of pure one.

[4] Harder the material greater will be the wear resistant property. CuO Nanoparticles reinforced composites have lower wear rate compared to base material.

[5] The wear rate at 100^{o}C heat treated 1.0% CuO filled composite is in terms of 10^{-3} g/mm, where as the wear rate of pure epoxy is in terms of 10^{-1} g/mm.

[6] Increase in addition of CuO Nanoparticles to the epoxy, decrease the mechanical properties of the composites.

6. REFERENCES

[1] K.V.P.Chakradhar et al., "Epoxy/Polyester Blend Nanocomposites: Effect of Nanoclay on Mechanical, Thermal and Morphological Properties", Malaysian Polymer Journal, Vol. 6, No. 2, p 109-118, 2011.

[2] F. Shehata, M. Abdelhameed, A. Fathy, M. Elmahdy "Preparation and Characteristics of Cu-Al2O3 Nanocomposites" Open Journal of Metal, 2011, 1, 25-33.

[3] Dan Guo, Guoxin Xie and Jianbin Luo. "Mechanical properties of nanoparticles: basics and applications". Journal of Physics D: Applied Physics, Volume 47, 3 December 2013.

[4] Singh J, Kaur G, Rawat M. "A Brief Review on Synthesis and Characterization of Copper Oxide Nanoparticles and its Applications". J Bio electron Nanotechnology 2016; 1(1): 9.

[5] Wei Gao, Jinzhen Cao, D. Pascal Kamdem"Effect and mechanism of nanosize copper oxide on some physical and mechanical properties of flake boards" Maderas, Cienc. Technology. Vol. 13(2): 203-210, 2011.

[6] Sunny AT, Vijayan P, Adhikari R, Mathew S, Thomas S. "Copper oxide nanoparticles in an epoxy network: microstructure, chain confinement and mechanical behavior" Phys Chem. 2016 Jul 20;18(29):19655-67.

[7] Yoshio Kobayashi , Yuki Abe, Takafumi Maeda, Yusuke Yasuda, Toshiaki Morita "A metal–metal bonding process using metallic copper nanoparticles produced by reduction of copper oxide nanoparticles" Technology Volume, April–June 2014, Pages 114–121.