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Mechanical Characterization of Copper Nano-Particles based Glass Fibre Reinforced Polymer Composites

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Abstract-Polymeric composites are being used extensively used in aerospace, automobile, transportation, chemical, construction and logistics industries. Copper Nanoparticles reinforced GFRP composites have been fabricated to enhance electrical and thermal properties. This project focuses on the addition of the copper nanoparticles and glass fiber reinforced in epoxy-based composites and their properties were probed using certain techniques which include tensile, impact and micro hardness. It was observed that properties mentioned before were enhanced due to the addition of CuNPs. Microscopic characterization was investigated by using Scanning electron microscope and it was observed that CuNPs and glass fibers are properly dispersed in epoxy. After performing the tests, with 8 wt.% of CuNPs and glass fibers better results (tensile, impact and micro hardness) are obtained which favors the material to be used in automotive and aerospace application to some extent.

Keywords-Copper Nanoparticles (CuNPs), Glass Fiber, Epoxy, Mechanical Characterization

I. INTRODUCTION

Composites was prepared experimentally reinforced with copper powder filled polypropylene with varying the copper powder content weight percent [i, ii]. And fabricated by using injection molding method. And results showed that micro hardness, density and impact strength increases by the addition of copper particles in polymer [i]. And observed that at 5vol. % of 20 Nano meters of copper powder showed optimum properties which was experimentally determined by mechanical, electrical and thermal characterization. It was observed that 5vol.% of loading and 20 nanometer particle size of copper and silver give slightly same electrical conductivities such as 0.01 and 0.02 S/cm respectively [ii].

Reference [iii] Copper/low-density-polyethylene Nano composites were fabricated in single screw-extruder using melt-blending method, hand lay-up method. [iii, vi-vii]. They were light weight, thermally conductive and anti-corrosive composites [iv] And it was observed that it is hybrid composite of copper and copper is properly dispersed in matrix. After performing TGA results were obtained and it was observed that thermal stability increases when copper Nanoparticles added to that Nano composite [iii, vi]. But it was also observed that it formed clusters when added higher copper contents and percolation paths of copper are also formed in polyethylene matrices [vii]. By using SEM analysis, it was observed copper oxide is homogeneously mixed in polyethylene [iv, vi]. It was also observed that pure high density polyethylene has thermal conductivity 8 times lower than copper oxide Nanoparticles composite [iv].

Nano composites fabricated reinforced with copper nanoparticle filled epoxy with three different medias such as air, epoxy fluid, and chloroform solution. By observing through a microscope, it revealed that the best filler distribution in the epoxy matrix showed by the copper Nano-particles ultra-sonicated with chloroform solution [v].

Composites fabricated using hand lay-up method by changing reinforcements (Al2O3, SiO2 and TiO2) and their percentage [viii-ix]. After doing all experimental work and getting all results, conclusion can be made that in case of SiO2 modified epoxy mechanical properties increases such as flexural strength, flexural modulus and ILSS, as compared to other modified composites [viii]. And it observed that when AL2O3 particles contents were increased then shear strength and ultimate tensile strength decreased [ix].

GFRP composites fabricated by adding silicon carbide filler and same for copper filler. it was investigated that silicon carbide filled glass fiber reinforced epoxy composite shows better properties than unfilled glass fiber reinforced epoxy composites [x]. Example of a GFRP based aerospace structure includes Airbus A350 that has its wing structures and fuselage primarily prepared from carbon fiber reinforced polymers [xi]. Previous researches show that copper ranging at Nano-scale size combine with epoxy would perform in better way in the applications of some composite materials but mostly researches related to the thermal and electrical conductivity. But different researches focused on mechanical properties of GFRP composites fabricated by hand lay-up method, but they are not using copper Nanoparticles as reinforcement.

In this project Glass Fiber is used in addition to copper nanoparticles mixed with epoxy to study their effect on physical and mechanical properties of epoxy. Physical properties undergo the study of microstructure of epoxy-copper and glass fiber composite. On the other hand, mechanical properties will be studied by observing the stress-strain behavior, by tensile testing. And hardness and impact strength also be measured by test techniques using ASTM standards. The basic aim to observe the influence of the copper nanoparticles and glass fiber added to the epoxy by carrying out different experiments so that one should come to know how they are related to improve the performance of epoxy in practical applications. To enhance the quality of epoxy with respect to its application the most suitable state of properties can be used in the material selection by comparing the properties. Tensile properties are the part of mechanical properties which will be measured from samples prepared. Tensile properties may provide useful data for engineering design purpose. And useful data can be obtained by the impact testing by using the charpy/izod. Sometimes every data is not considered valid for every environment since thermosetting plastics possess high degree of sensitivity to rate of strain and environmental conditions. Nevertheless, data obtained can still be discussed and it is strongly expected that different sample with different percentages of copper nanoparticles and glass fiber will provide the different results. This data will be used to characterize the mechanical properties of CuNP's based GFRP composites in this research.

II. EXPERIMENTAL SETUP

Epoxy based composites were prepared reinforced with copper nanoparticles and glass fibers by using hand lay-up method. Compositions of these composites are given below.

1. Pure hardened epoxy (control element)
2. Epoxy +2% of (copper nanoparticles and glass fiber)
3. Epoxy + 4% of (copper nanoparticles and glass fiber)
4. Epoxy + 6 % of (copper nanoparticles and glass fiber)
5. Epoxy + 8% of (copper nanoparticles and glass fiber)

A mold was prepared with suitable size to get specimens for tensile, impact and hardness test, mold was made just like a tray with the dimension which is 12inches × 6 inches × 1inch. After preparing that mold apply wax on mold for finished and polished surface and treated with a release agent. The next step is to apply epoxy layer into the mold carefully and slowly. It should be noted that only the mixture of epoxy and its hardener with 1:1 ratio should be stirred in a plain paper cup for 5 minutes. After stirring the mixture is poured into the mold and rolling process is carried out to uniform the thickness with the help of roller.

After carrying out these all steps finally mixture within mold is left at room temperature for curing process in 24 hours of time for purely epoxy sample with no addition of copper nanoparticles and glass fiber. After curing process samples drawn out from mold. Other samples are also prepared with the procedure as described above with one slight changing in the mixing steps. During mixing epoxy and hardener different percentages of copper nanoparticles and glass fiber is also added to observe the effect of them on the physical and mechanical properties of the epoxy.

After preparing all sample these samples were cut to prepare different specimens to determine different properties such as micro hardness, tensile, impact test and microscopic study. These specimens were prepared according to the ASTM standards [xii].

To look upon the effect of the Copper Nanoparticles and glass fiber into the epoxy hardness test is performed by using Micro Vickers hardness testing machine [xiii]. In this testing machine probe is brought on the surface and load is applied ranging 1 to 1000 grams [xiv]. In this test 50grams load is applied for 10 sec. Fig. 1 shows physical appearance of all micro hardness specimens

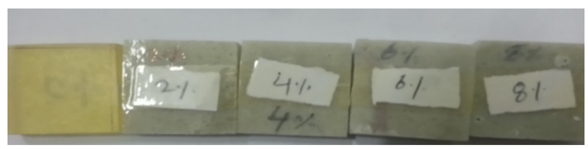

Fig. 1. Micro hardness Specimens

To determine the different properties such as tensile strength and modulus of elasticity tensile test is performed on that material. And this test is performing on shimadzu 20KN universal testing machine to get the tensile properties. This test is performed under defined conditions of humidity, temperature, pre-treatment and testing machine speed [xv-xvi]. This test was performed according to the ASTM standard D5083-02 made for plastics [xvii]. Tensile test specimens can be seen in Fig. 2.

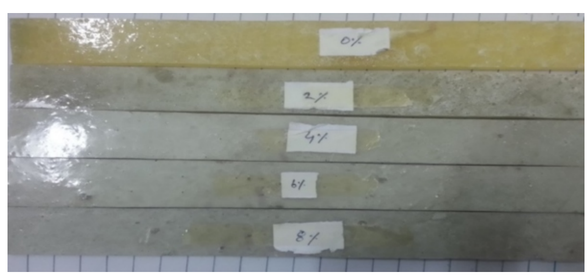

Fig. 2. Tensile test Specimens

To determine this property test was carried out that is known as Charpy Impact Test. Sample was prepared using ASTM Standard 6110 D (08.03) [xviii]. In this test JBW 300 impact testing machine is used to perform impact test. Impact test specimens can be seen in Fig. 3.

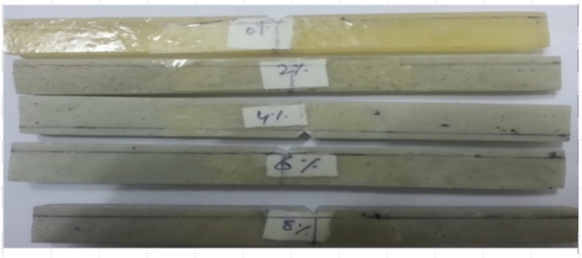

Fig. 3. Impact Test Specimens

Study of structure of any material is call morphology. And in this research TESCAN VEGA 3 scanning electron microscope was used to observe structure of epoxy-based composite. And we know that epoxy is not conductive material so to make it conductive gold-palladium layer is coated on epoxy by vacuum sputtering process. And after that structure was examined [xix].

III. Results and Discussion

A. Hardness Test

Variation in hardness was found for different volume %age of reinforcement in Fig. 4. And here we can see that there is variation in hardness results with different volume percentages and this variation is due to uneven dispersion of copper nanoparticles and glass fibers. Hardness of first sample is less than all other samples which is about 11.333 hv. And on the other hand, sample 5 has more hardness than other samples which is about 20.8 hv.

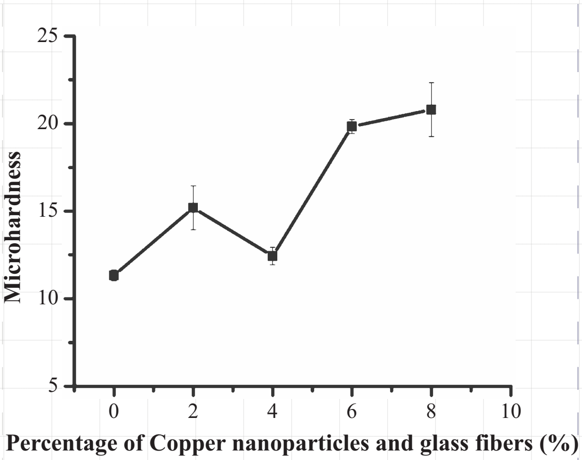

Fig. 4. Graph of Micro Hardness variation of epoxy-based composites samples.

B. Tensile Loading

The load-displacement data obtained for each specimen was converted to plots of stress-strain and were examined to evaluate mechanical properties. Fig. 5 shows the tensile strength of various samples. Lowest strength is of sample 1 which is pure epoxy and its strength is 13.8896MPa. The maximum tensile strength 40.9573 MPa was shown by composite sample 5.

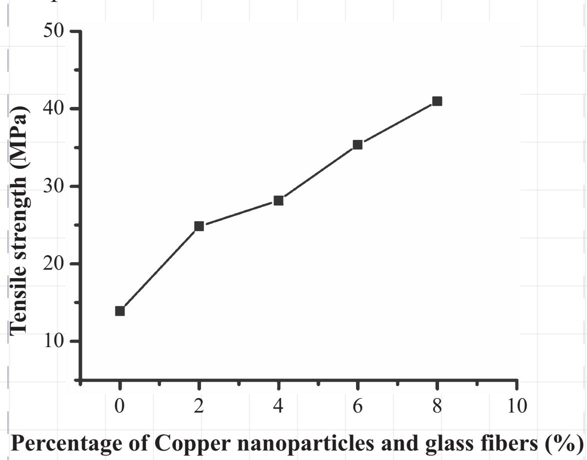

Fig. 5. Graph of tensile strength variation of epoxy based composites samples.

C. Impact Test

Impact test was performed on epoxy-based composites. Fig. 6 shows the impact strength of these composites and sample 1 has low impact strength compared with other samples which is 1joule and sample 5 has more impact strength than other composites. It means that by addition of the copper nanoparticles and glass fiber impact strength increases.

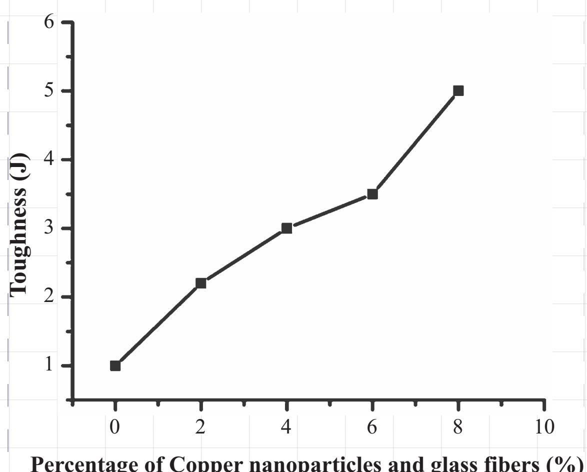

Fig. 6. Graph of impact strength variation of epoxy-based composites samples.

D. Fracture Characterization Using Sem

Microscopic study was performed on copper nanoparticles-glass fiber reinforced epoxy-based composites using scanning electron microscope. Dispersion of copper nanoparticles and glass fibers can be seen in the Figures 7-10 below. From these results, we can observe that CuNPs and glass fibers are properly dispersed in epoxy with 2wt.% of CuNPS and GF. But by increasing the wt. % of CuNPs and GF agglomeration occurs as shown in Fig.10.

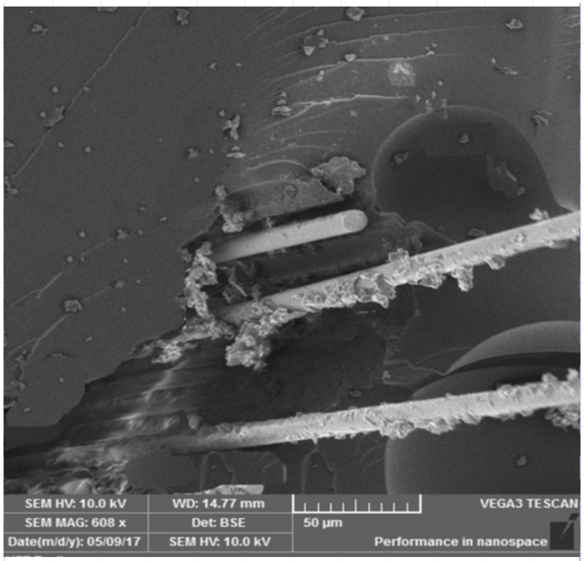

Fig. 7. 2% of (CuNps and GF)

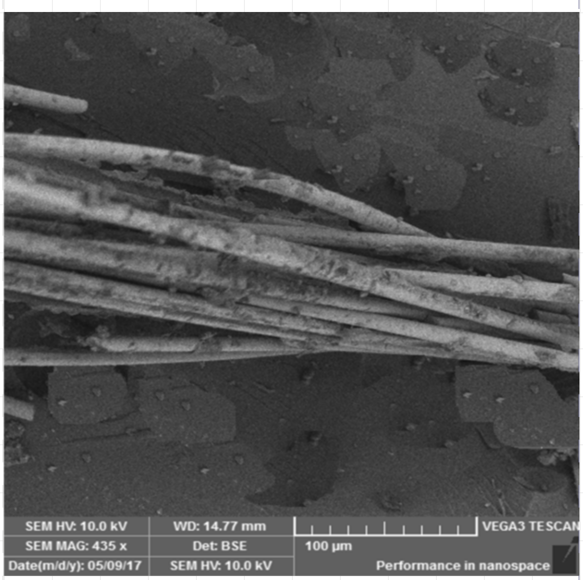

Fig. 8. 4% of (CuNPs and GF)

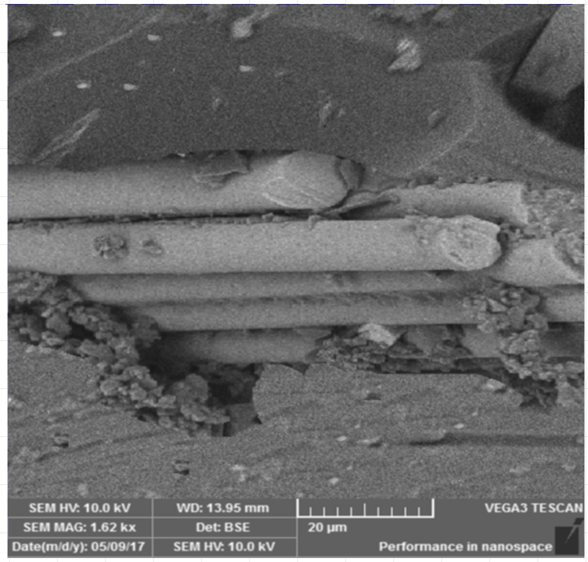

Fig. 9. 6% of (CuNPs and GF)

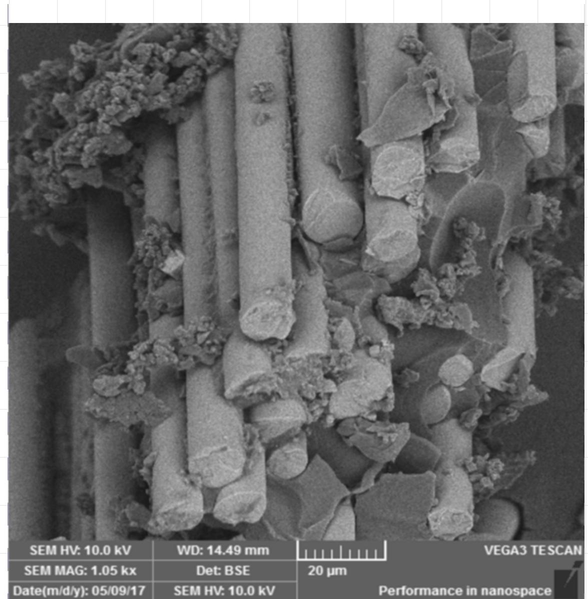

Fig. 10. 8% of (CuNPs and GF)

IV. CONCLUSION

Polymers can be strengthened with the addition of reinforcement in form of Nano particles to make composite that possess greater extent of hardness and strength. Addition of copper nanoparticles and glass fibers up to 8% copper nanoparticles and glass fibers showed highest tensile strength of 40.9573MPa. Maximum Micro hardness was shown by the composite containing 8% copper nanoparticles. But somehow there was variation in hardness and that was due to improper distribution of reinforcement. Maximum impact strength was also achieved by 8% copper nanoparticles and glass fibers. It is observed that epoxy shows good and reasonable physical and mechanical properties in combination with Copper

Nanoparticles and glass fibers and it can be made an industrial product. There are some shortcomings like porosity, un-even distribution of the Copper Nanoparticles and glass fiber pieces which becomes cause of lacking strength and improper adhesion between the epoxy atoms and filler. These shortcomings can be improved by using the proper preparation technique because sample preparation plays vital role in determining the behavior of the physical and mechanical properties of the material product. Uneven distribution of the Copper Nanoparticles and glass fibers can be improved by using mechanical stirring for mixing and sample preparation must be carried out in vacuum environment or any other technique must be used during process of preparation to avoid the air bubbles form the mold so that porosity should suppress to improve the mechanical as well as physical properties. During these weight percent reinforcement 8% reinforcement is preferred because it shows the good behavior of properties as compared to the other weight percent reinforcement. From the above-mentioned results, it is recommended that if weight percent reinforcement increase properties of the composite would further improved but its fracture behavior would shift to more brittleness.

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