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Mechanical Characterization of Nano Filler Filled Polymer Hybrid Composite

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Abstract: *The composite materials have been widely used not only for aerospace/aeronautics applications, but also in automotive, sports and construction industries. In the present study, the effect of nano alumina (Al_2O_3) particles on Nickel coated short carbon fiber reinforced epoxy (CF/Ep) nano composite was investigated for the enhancement of Mechanical properties. For this purpose different proportions (0, 2, 4 & 6 wt. %) of alumina (Al_2O_3) nanoparticles were reinforced in the Nickel coated Short carbon fibre reinforced epoxy composite in order to study the influence of nanoparticles. Test samples were prepared using open mould process method and machined according to ASTM standards. The hardness test showed that increase in filler content, hardness of the composite also increased and showed highest value (87.8) at 6 wt% filler loading. The tensile test revealed the increase of tensile strength and modulus as the filler loading increased (29.52Mpa and 2.73GPa) up to 4% and then started decreasing further addition of the alumina filler*

Keywords: Epoxy, Alumina, Carbon Fibre, Hardness, Tensile

I. INTRODUCTION

Polymer Matrix Composites are replacing traditional materials such as aluminium, steel, and others (PMC). Polymer-based composites are most commonly used in automotive, construction, aerospace, and other industries for various applications due to ease of fabrication/processing, high specific strength, and stiffness [1]. Thermoset and thermoplastic polymers are used with short/continuous fibres such as carbon fibre, glass fibre, and others. Fiber reinforced polymer composites are preferably used in various applications due to their numerous mechanical properties, such as high specific stiffness, high corrosion resistance, better thermal stability, better fatigue resistance, and firmness in the manufacture of complex shapes [2, 3]. The various mechanical properties and fracture toughness of polymer matrix composites are largely be contingent on the type of matrix and reinforcement used, type and orientation of fiber used, type, size, shape and dispersion of fillers used.

Also, these improvements are attained using conventional fabrication techniques without any defects in processing which leads to effect on density of polymer matrix composites [4]. The polymer composites reinforced with laminated fiber such as epoxy/carbon fiber composites are extensively used in automotive, structural and aerospace industries [5, 6]. They exhibit high strength-to-weight and stiffness-to-weight ratios. These polymer composites have exclusive advantages over monolithic materials, such as high stiffness, high strength, long fatigue life, better resistance to wear and corrosion, and better environmental stability [7]

The hardness of the composites increased with increasing filler content. Again, the rigid fillers increased the hardness of the epoxy resin. Apart from fly ash and nano clay-filled epoxy composites, all composites followed an increasing profile with increasing filler content [8]. It is observed that increase in addition of Al_2O_3 and hematite to composites leads to increase in hardness number this may be due to the improved bond between the matrix and reinforcement, reduced porosity [9]. The research work confirms that addition of nano filler enhances the hardness of the polymer composites [10]. In some of the literature works also evident the increase of hardness value of the composite by the addition of filler [11,12]

Based on extensive literature reviews, only few works has been carried out on nickel coated short carbon fiber reinforced epoxy composites with nano fillers at various proportions. In this present study an attempt has been made to enhance the Hardness and Tensile properties of nano filler filled nickel coated short carbon fiber reinforced epoxy composites.

II. MATERIALS AND METHODS

2.1 Materials

Epoxy based polymer composites reinforced with Nickel coated carbon fiber was prepared by adding filler as aluminium oxide particles (<100nm) by 2%, 4% and 6% weight fraction by open mould process. Epoxy, fiber and Nanoparticles were weighed properly for the above said percentages and using rule of mixtures, samples were prepared. Wooden moulds (cost effective) were prepared for sizes 100mmx120mmx4mm and 100mm x 65mm x10mm. The wooden strips were then placed on a granite plate maintaining horizontal position of mould. Wax was coated on the inside and boundaries of the mould prepared. This wax provides coating for the casting to be removed easily after curing. Aluminium oxide nanoparticles for different percentages were mixed thoroughly in epoxy before adding hardner and was stirred mechanically. This stirring continued till uniform distribution was observed. After thinning of epoxy and uniform distribution of Nanoparticles, add short fibers and continue the stirring. Again, after uniform distribution of nano particles and fibers and stirring continued for uniform distribution of hardener and the mixture was poured into the mold cavity (Figure 1(a)) concentrating the pouring to a point. The mixture occupies the mould dimensions. The mould was allowed to cure at room temperature for 24 hours. The prepared mould was investigated for any damages or complexity and were removed carefully form the mould (Figure 1(b)). As wax was coated the samples were removed easily (Figure 1(c)). The samples were then post cured for 80oC for 3 hours in a conventional oven. Post curing was done to ensure the completion of cross linking of polymer chains with the Nanoparticles. The composite material prepared was carefully removed from oven after cooling down naturally for 12 hrs. The material was then cut by water jet cutting (Figure 1(d)) for required dimensions according to ASTM standards.

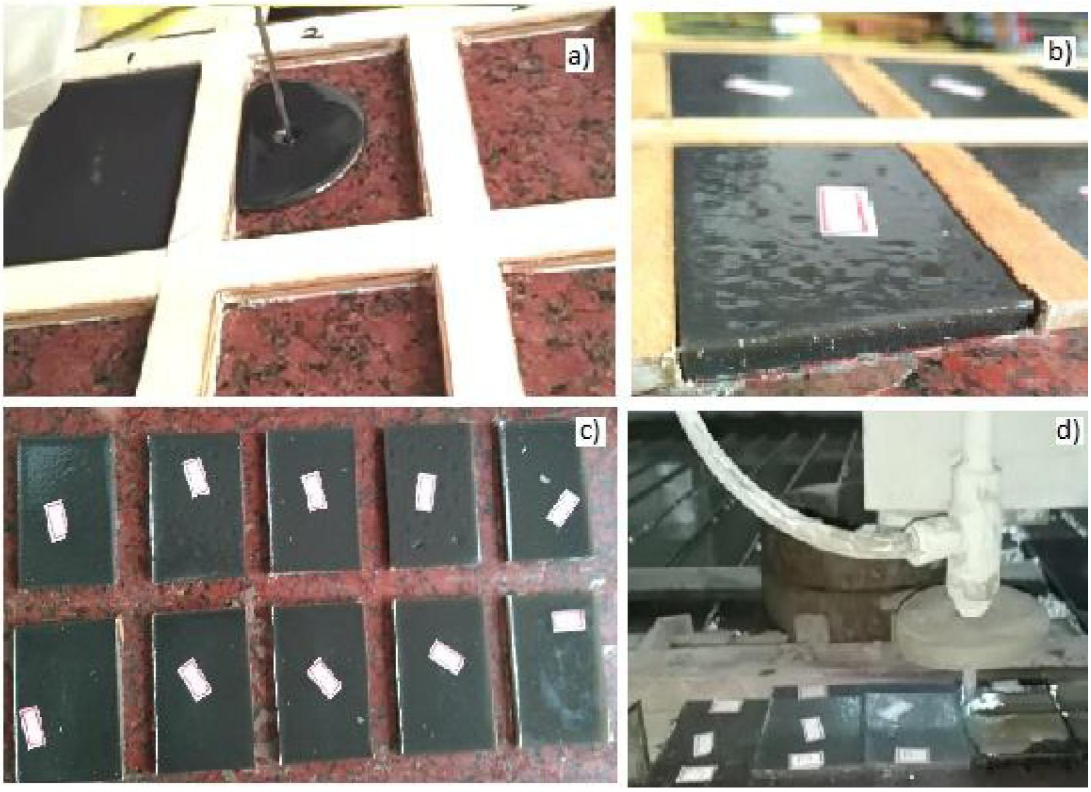

Fig 1: a) Pouring Mixture into cavity b) removing prepared samples c) Samples d) Water jet cutting for required dimensions

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Table 1: Details of specimen composition of composites

Sl. No	Composite Material	Carbon fabric (wt. %)	Epoxy (wt. %)	Filler (wt. %)
1	NCF-Ep (NCEp)	2	98	0
2	2% Al_2O_3-NCF-Ep (NCEp-2A)	2	96	2
3	4% Al_2O_3-NCF-Ep (NCEp-4A)	2	94	4
4	6% Al_2O_3-NCF-Ep (NCEp-6A)	2	92	6

III. EXPERIMENTS

3.1 Hardness Test:

Hardness is defined as the resistance of a material to permanent deformation such as indentation, wear, abrasion, scratch. Principally, the importance of hardness testing has to do with the relationship between hardness and other properties of material. The hardness test is a mechanical test for material properties which are used in engineering design, analysis of structures, and materials development. The principal purpose of the hardness test is to determine the suitability of a material for a given application, or the particular treatment to which the material has been subjected. Shore D Hardness test is been conducted for the fabricated composites as per the ASTM D2240 [13]. Figure 2 represents the shore D hardness tester.

Figure 3: Shore D Hardness Tester

3.2 Tensile Test:

To determine the ultimate tensile strength and young's modulus of the composites tensile test has been conducted. The test specimens were prepared as per ASTM D638 standard of dimensions 165 mm x 19 mm x 4 mm [14]. The tensile test was carried out on Kalpak-100K computerized universal testing machine under displacement control with a crosshead speed of 2.5mm/min. **Figure 3** shows tensile test specimen fixed on tensile test apparatus.

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Figure 3: Tensile test experimental setup

IV. RESULTS AND DISCUSSION

4.1 Hardness

Wear of the material is having direct relation with the hardness of that material hence it is necessary to conduct hardness test. Conduction of hardness test reveals the variations of hardness property of the material by varying the weight percent of the filler materials. The hardness values of the fabricated composites are tabulated in table 2.

Table 2: Shore D Hardness Value of the Composites

Sl. No	Composite Materials	Hardness (Shore D)
1	NCEp	78
2	NCEp-2A	82
3	NCEp-4A	84.6
4	NCEp-6A	87.8

This is confirmed from the Figure 4 that hardness values increased from 78 to 87.8. This increase of the hardness values is due to because of the increase of the wt% of the filler content in the matrix material.**Figure 4** shows the hardness values of the composites.

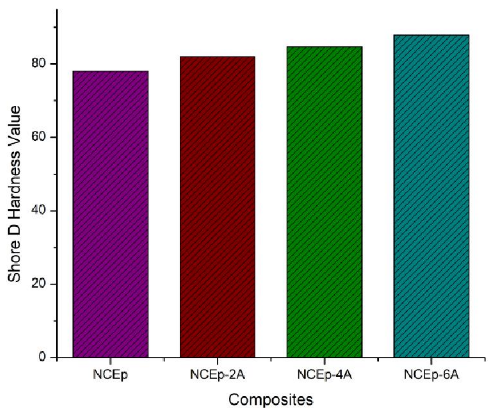
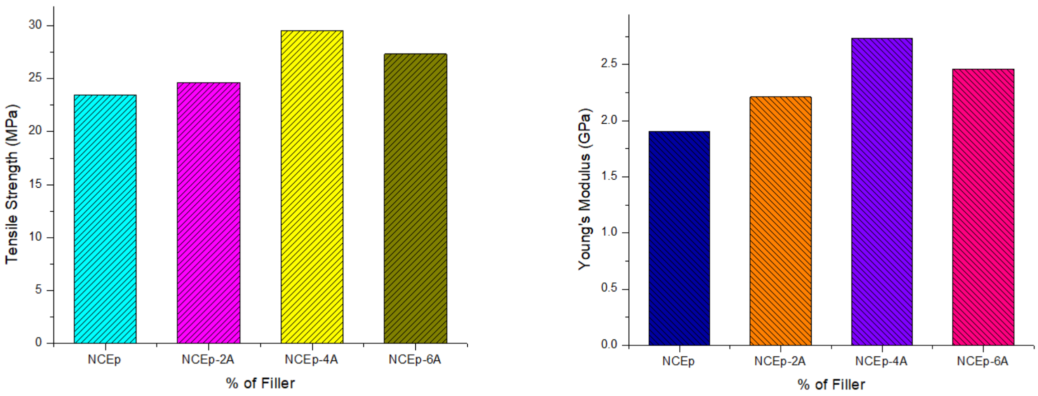


Figure 4: Shore D Hardness Results of the Composites

The composite NCEp-6A having 6% of alumina filler possess higher (87.8) value of hardness which is 12.56% increase value compared to NCEp composite. The enhancement of hardness value of the composite is because of filler addition. This could be as a result of the Al_2O_3/Epoxy binding strength. Because it is a ceramic material, Al_2O_3 has a substantially higher surface hardness. Consequently, the addition of Al_2O_3 to epoxy enhanced its hardness. [15]. Further, the filler-matrix interface increased adhesion strength enhanced the material resistance to indentation [16].

4.2 Tensile Properties

The findings of the tensile test are used to compute the tensile strength and young's modulus. According to the investigation, the tensile strength varied considerably with the reinforcement of different weight percentages of Al_2O_3 nano fillers. The NCEp composite have shown a tensile strength of 23.5 MPa. The tensile strength of 24.64 Mpa and 25.92Mpa was recoded in NCEp -2A and NCEp-4A respectively. NCEp-6A recorded tensile strength of 27.35 Mpa. The highest tensile strength was recorded in NCEp-4A. The superior characteristics of the carbon fabric, the good degree of the interfacial bonding between the reinforcements and matrix, and the extremely low values of void volume fractions are all responsible for the improvement of tensile properties in the current study [17, 18]. When fillers exceed >4 wt% (NCEp-6A) large number of nanoparticles participate leading to agglomeration in the final composite which cause for the reduction in tensile strength of the composite.



(a) (b)

Figure 5: Tensile properties of the composites (a) Tensile Strength (b) Young's Modulus

The Young's Modulus of the composites also follows the same trend as like Tensile strength. Highest Young's Modulus 2.73 GPa was recorded in NCEp-4A. **Figure 5** depicts the Tensile properties of the composites

V. CONCLUSION

In this present study the effect of nano alumina filler on Mechanical properties of Nickel coated short carbon fiber epoxy composite were carried out and following conclusions are derived.

- Hardness property of NCEp composites were improved with addition of nano alumina as filler. Addition of filler wt% increases the Hardness value also increases.
- The Tensile properties of the composites have been enhanced by the reinforcement of Al_2O_3 nano fillers. The inclusion of secondary reinforcements up to 4 wt.% significantly enhanced the tensile strength and tensile modulus of hybrid composites.
- In terms of tensile characteristics, NCEp-4A composites have performed better, because higher interfacial adhesion between matrix and fabrics.
- It is confirmed that addition of Al_2O_3 nano fillers enhances the composite properties.

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