# Effect Of Nano $Al_2O_3$ Addition On The Mechanical Properties Of GFRP Reinforced By Mwcnts

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**Abstract:** In the scientific literature, nanocomposite materials are widely studied because they introduce considerable improvements in the properties even at a low nanoparticular content. In the present paper mechanical properties of $Al_2O_3$/ GFRP reinforced by MWCNTs were studied. The $Al_2O_3$ nanoparticles are mixed with vinyl ester resin using ultrasonic bath sonicator in different weight fractions of 0, 1 and 2% with a constant weight fraction 0.5% of MWCNTs in all composites. E-Glass fiber (chopped strand mat) is used as fiber reinforcement. The effect of $Al_2O_3$ nanoparticles addition on the mechanical properties such as hardness, flexural and tensile strength were investigated. It was founded that addition of $Al_2O_3$ to (GFRP/0.5 wt% of MWCNTs) improves the mechanical properties of composites.

**Keywords:** $Al_2O_3$, MWCNTs, nanoparticles, E-glass fiber, Mechanical properties, vinyl ester, polymer nanocomposites.

## 1. INTRODUCTION

Glass fiber reinforced polymer composites are a compulsory material and are widely used in various fields of engineering, like aerospace, construction, transportation, auto motives industry and sports goods [1]. GFRP materials include increasing applications because of their high density-to-density ratio, high resistance, high corrosive strength, low thermal expansion coefficient, as well as greater production feasibility in comparison with conventional engineering materials [2] The particles modification procedure is usually used on the composites to enhance the mechanical properties of FRP composites. The most commonly used are thermoplastic particles, rubble particles, and rigid particles [3-8]. Nano-particle-filled composites are known as nano-composites (NCs). In the polymer matrix the nano particles are uniformly dispersed. Because of its size, nanocomposites have higher characteristics than conventional composites due to their high interfacial adhesion [9-13]. Nano reinforcement like nano carbon tubes and nano silica and other nano particles were used to modify polymer composites. Many investigations concentrate on the mechanical properties of the enhanced composites [14-20]. Kanagaraj [21] founded that by the addition of CNT Young's modulus is rapidly increased also toughness and ultimate tensile strength linearly increased. Allaoui et. al. [22] studied effect of multi walled carbon nano tubes/epoxy on the mechanical and electrical properties reported that young's modulus and yield strength were significantly improved by introducing CNs. Liu et al. [23] investigated the effect of MWCNTs polymer composites, they founded that great enhancement in the tensile modulus and the yield strength.


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Yang et al [24] dispersed MWCNTs nano tubes in polymer matrix the results showed that the mechanical properties and thermal properties are obviously improved. Lim et al. [25] studied tribiological behaviour of carbon/ carbon composites they concluded that rates of wear and friction are reduced by adding CNTs. Schadler et. al. [26] Studied the Epoxy/ MWCNTs composite load transition and they founded great improve in compression modulus. A technique was used to distribute DWCNTs within epoxy matrix by Gojnyet et al. [27] by comparing results of adding same weight ration of carbon black and nanotubes they found that higher improvement of mechanical properties of nano tubes addition than carbon black. Also, Results showed that tensile strength of epoxy/ nanotube, elastic modulus and fracture toughness were improved. Shekar et al. [28] homogenously dispersed MWCNTs in polymers matrix. They reported that both the flexural force and flexural modulus are improved due to presence of MWCNTs within epoxy composites. Breton [29] introduced various MWCNTs kinds to modify polymer resin. The results indicated that enhancing polymer matrix by 1, 3 and 6 wt% leads to increase tensile modulus. In the present study $Al_2O_3$ nano particles are added with 0, 1 and 2 wt% to modify E-Glass/Vinyl ester composite reinforced by 0.5 wt% as a constant weight percent. All composites were fabricated using hand layup technique.

## 2 MATERIALS

### 2.1 Preparation of Nano Composites Specimens

Fig.1 shows E-glass fiber, chopped strand mat (CSM) of Fiber lengths between 20 and 30 mm and 450 g / $m^2$ fiber mass. It was used to reinforce vinyl ester matrix. Fibers and vinyl ester were obtained from Al JoumhouriaCo. Cairo, Egypt. The wood mold was initially cleaned and the wooden plates were covered with the release agent. Both vinyl ester resin and hardener were mixed in a beaker with a 1:10 ratio using stirrer then the mixture is uniformly applied on the wooden mould surface. The mold was fitted and placed with a square piece of E-glass fiber with the same size. MWCNTs nano particles (particle size 7-15 nm, length 0.5-10 µm) and $Al_2O_3$ nano powder (particle size <50 nm, surface area >40 $m^2$/g) were purchased from Sigma-Aldrich. To be sure that $Al_2O_3$ nanoparticles are uniformly dispersed into polymer resin

without agglomeration an ultrasonic bath sonicator, (model CO-Z, 760-Watt power & 40 kHz frequency) was used. $Al_2O_3$ nanoparticles of 0, 1 and 2% and a constant weight fraction 0.5% of MWCNTs were firstly kept in distinguished beakers. The beakers are maintained in an ultrasonic bath under vibration for 2 hours. The previous mixture is then kept for an additional 4 hours in a rotating shaker to confirm well dispersion without agglomeration of $Al_2O_3$ nanoparticles within polymer matrix. Then a layer of $Al_2O_3$ + MWCNTs / polymer resin was passed through one roller after that a square layer of Chopped strand mat (CSM) is introduced upwards the previous nanofiller/polymer layer. This step is repeated until an approximately 3 mm thickness is reached. The top wooden plate is now placed on the layers and a weight is added. At room temperature the composite was then treated for 24 hours. The specimens were cut according to ASTM standards. Specimens and their composition are shown in table 1. Figure 2 shows the fabricated composite photo.

***Fig.1*** *E-glass fiber type: chopped strand mat (CSM)*

***Fig.2*** *Photo of the fabricated composite.*

***TABLE 1***
*SAMPLES COMPOSITION*

| *Sample* | *Combination* | *wt%* |
|---|---|---|
| $S_1$ | E- Glass fiber | 39.5 |
| | vinyl ester resin | 60 |
| | $Al_2O_3$ | 0 |
| | MWCNTs | 0.5 |
| $S_2$ | E- Glass fiber | 38.5 |
| | vinyl ester resin | 60 |
| | $Al_2O_3$ | 1 |
| | MWCNTs | 0.5 |
| $S_3$ | E- Glass fiber | 37.5 |
| | vinyl ester resin | 60 |
| | $Al_2O_3$ | 2 |
| | MWCNTs | 0.5 |

## 3.1 MECHANICAL PROPERTIES

The mechanical characteristics such as Hardness, Tensile Strength and Flexural Strength were performed to study the influence of nano filler, for measurements of the hardness of specimens according to ASTM D-2583 (Fig. 3), the hardness tester (Barcol hardness test model 934-1) was applied. The specimen was put under the Barcol hardness check indentor and under a constant pressure for the optimum dial indicator then the profound penetration was translated into absolute barcol numbers. Around eight samples were tested and the average value for each nanocomposite was selected.

***Fig.3*** *Barcol Hardness equipment*

Tensile test was carried out using WAW-300B (300 kN, Zhejiang Jingyuan Mechanical Equipment Co., Ltd., Jinhua, China) Fig.4. Experimental tests were performed according to ASTM D 638 IV as shown in Fig5. The samples prepared for testing are shown in Fig.6. Five samples were checked for each nanocomposite and an average value was selected. Testing results are given in table 2.

***Fig.4*** *Universal Testing Machine*

ASTM D638 Type Ⅳ

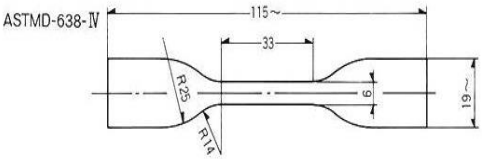


***Fig.5*** *ASTM D638 Type IV standard specimen.*

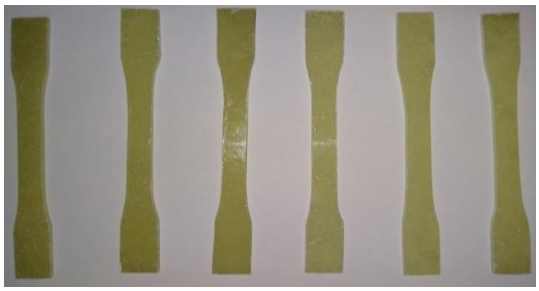

***Fig.6*** *Test Samples as per ASTM D638 Type IV*

***TABLE 2***
*MECHANICAL PROPERTIES OF GFRP/NANOFILLER COMPOSITES*

| Sample | Hardness (BHN) | Tensile Strength (Mpa) | Flexural strength (Mpa) |
|---|---|---|---|
| $S_1$ | 84.90 | 520.03 | 539.03 |
| $S_2$ | 91.64 | 570.17 | 577.19 |
| $S_3$ | 98.73 | 592.16 | 597.12 |

## 4 RESULTS AND DISCUSSION

Fig.7 shows Hardness variation of different weight percentage of nano aluminum oxide reinforces GFRP/MWCNTs. From this figure it is observed that by the addition of 1% wt of $Al_2O_3$ the Hardness value is elevated from 85.90 to 89.64 and by adding 2% wt of $Al_2O_3$ the Hardness is significantly increased to 96.73. The hardness therefore increased by 7.9 % and 16.28 % by reinforcing with 1 wt.% and 2wt.% of nano aluminum oxide respectively. it is cleared that the hardness improved with the increase of the weight percentage of Al2O3 within composite.

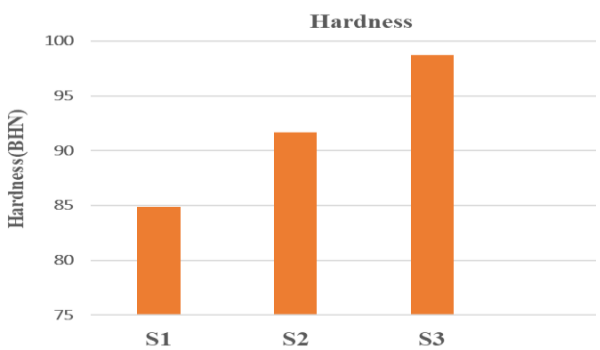


***Fig.7*** *Hardness variation of different samples*

Fig.8 indicates tensile strength comparison among the different three samples from this figure it can be shown that the $S_1$ sample is less tensile strength value, since it was made without aluminum oxide mixing, while sample $S_3$ has the largest value of tensile strength because it contains 2 wt.% of nano aluminum oxide. Its cleared that the addition of 1wt.% and 2wt.% of $Al_2O_3$ enhanced the tensile strength of sample $S_2$ and $S_3$ by 9.6% and 13.87% respectively.

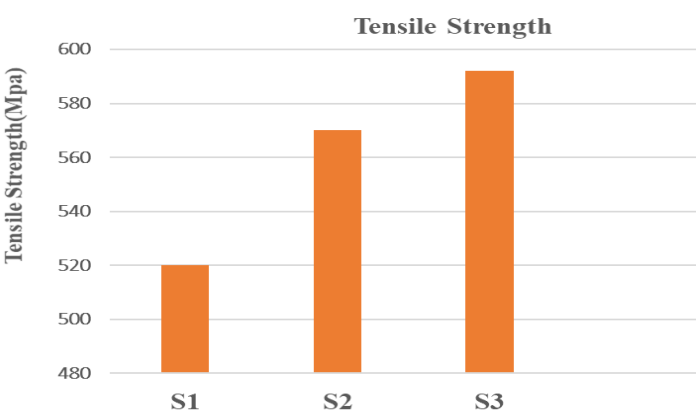


***Fig.8*** *Tensile strength comparison among the different samples*

Flexural strength variation of GFRP/MWCNTs composites during reinforcement of $Al_2O_3$ weight percentage is shown in Fig.9. Its cleared that the addition of 1wt.% and 2wt.% of $Al_2O_3$ enhanced the flexural strength of sample $S_2$ and $S_3$ by 7.07% and 10.77% respectively. It is shown that the flexural strength increases with the increase of nano $Al_2O_3$ weight percentage.

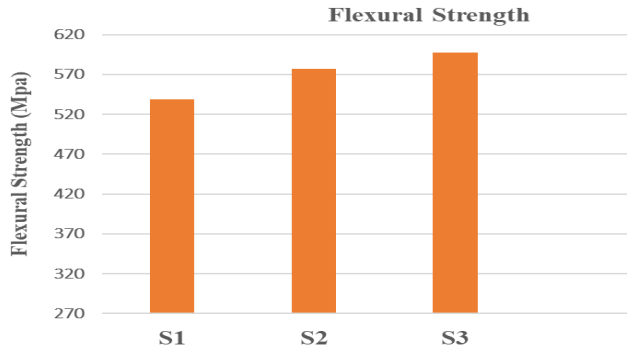


***Fig.9*** *Flexural strength variation of different samples*

From the previous experimental results, it can be seen that by the increase of the weight percentage of $Al_2O_3$ nano particles in GFRP/MWCNTs composite the mechanical properties were significantly improved. The explanation for these is that there is a strong bond between the nanofiller and the polymer matrix.

## 4 CONCLUSIONS

hand layup technique was used to fabricate GFRP/MWCNTs $Al_2O_3$ is added by 1wt.% and 2wt.% and MWCNTs is add by a fixed ratio of 0.5wt.%. To be sure that the particles is homogenously distributed without agglomeration. Nano fillers are dispersed within vinyl ester resin using ultrasonic bath sonicator. The influence of Al2O3 addition to GFRP/MWCNTs on the mechanical characterization such as hardness, tensile strength and flexural strength was studied. From the results it is clearly shown that with increase in weight percentage of aluminum oxide in the GFRP/MWCNTs composites the mechanical properties enhanced effectively.

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