Studying the effect of Polyamide 6 Nanofibers on Physical and Chemical Properties of Unsaturated Polyester Reinforced by Glass fibers Composites

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Abstract.

In this study, the hybrid reinforcement materials of (glass fibers and polyamide 6 nanofibers) with 15% weight fraction added to unsaturated polyester (UPS). The physical properties (density, bending strength, impact strength) and chemical resistance of UPS reinforced with hybrid reinforcement (GF+PA6 nanofibers) with different ratios: (0.99:0.01, 0.98:0.02, 0.97:0.03, & 0.96:0.04) wt.% by 15% weight fraction were studied. Results proved that, the impact strength increased from 0.5 to 1.5 K.J/m², while the bending strength increases from (2 to 14.5) MPa with adding of (0.96:0.04) wt.% of reinforcement materials by 15% weight fraction. The weight loss of (UPS/GF) decreased from (1 to 0.1) with (0.04) wt.% of PA6 Nanofibers for 30 days and it stable at this value for 40 days, this is refers to increases of chemical resistance of samples in H2SO4 acid. The density of (UPS/GF) decreased from (1.29 g/cm³) to (1.01) g/cm³ for density of (UPS/19.96GF+0.04 PA6 Nanofibers).

Keywords: Electrospinning technique, water purification, polystyrene nanofibers, contact angle, hydrophobi

1. Introduction

Nano science and technology have a relatively broad area of research. It focuses on things that are measured in nanometers. Combining active nanomaterials with polymers is an influential way to obtaining improve performances and get new employment for the lightweight material implementations. The resulting polymer nanocomposites interest, from advantages of matrix phase and nano-reinforcement phase [1]. Fibre/polymeric matrix composite materials utilized in a many implementations as civil, aerospace, automotive and other [2].

Hybrid reinforcement phase used in many applications for superior physical and chemical properties, as: Detmoni et.al. 1914, studying the effect of silica micro particles on the flexural strength, bulk density and modulus of glass-fibre composites, he noted there are an enhancement of these properties.[3]

2008, Fu et.al, studying the particle size and particle/matrix interface adhesion on mechanical properties of glass-polymer composites, they noted there is an improvement raises from adding of nanoparticles to these composites.[4]

Jolio et.al 2016, manufactured and tested of mechanical properties, manufacturing parameters and particle loading of hybrid epoxy/carbon fiber composites with poly-di-allyldimethyl ammonium chloride-functionalized nanoparticle and micro silica. They noted there are an homogenous dispersion, diminution of the density and enhancement of the mechanical properties in the hybrid carbon fibers composites.[5] Brittle matrix fracture for long since represent the greatest problems in...
fiber-reinforced composites. Newly, the combining of electrospun nanofibers is an effective method for enhancing the mechanical properties of these composites, without process problems and negatively affecting other properties particularly mechanical properties [6-8]. Cristina M. et. al 2018, studying the effect of different electrospun nanofibers on mechanical properties of carbon/fibers epoxy composites. They noted, there are enhancement in flexural strength and mechanical energy of these composites [9].

2. Experimental:

2.1 Materials

1- Unsaturated polyester (UPS), with density (1.19 g/cm³), Sigma Aldridge company used as a matrix material, and ethyl methyl ketone used as a hardener of polyester risen.

2- Fiber glass specifications (EG) with density (2.5 g/cm³), China production used as the first type of a reinforcement material.

3- Electrospun nanofibers of polyamide 6 with diameter about 100 nm, prepared by electrospinning technique and used as a second type of a reinforcement material.

‘Figures 1. and 2’. show the reinforcement materials.

![Figure 1: Photograph image of glass fibers](image1)

![Figure 2: SEM Image of polyamide 6 Nanofibers](image2)

2.2 Methods

1- Electrospinning technique for prepared polyamide 6 nanofibers is used. 0.18% concentration of polyamide 6 dissolve in formic acid prepared by magnetic stirrer tool, it mix for 6 hr for homogeneous solution. It remain as stable solution for 3 hr for removing the bubbles from it.

2- It pumped through electrospinning machine for prepared the nanofibers under (25 kV power supply, 14 cm electrospinning gab, 0.48 mm needle diameter, and 0.5 ml/hr flaw rate).

3- Hand casting method used for prepared all the samples, (10*10) cm² mold of casting prepared for fabricated the sample, then it cut according to the standard measurements of each test as in table 1.

4- Different weight ratios of a reinforcement material prepared for composites and nanocomposites fabricated as in table 2.

| No. of test | Test                | Dimensions (length * width * thickness) |
|------------|---------------------|----------------------------------------|
| 1          | Density             | 5 cm * 5 cm * 1                        |
| 2          | Bending strength    | 12.7 cm * 1.2 cm * 1 cm                |
| 3          | Impact strength     | 7.5 cm * 1 cm * 0.5 cm                 |
| 4          | Weight loss         | 1 cm * 1 cm * 1 cm                     |
Table 2: Weight ratios of samples

| No. of test | UPE    | Glass Fiber | PA 6 nanofibers |
|------------|--------|-------------|-----------------|
| 1          | 100%   | 0           | 0               |
| 2          | 85%    | 15%         | 0               |
| 3          | 85%    | 14.99       | 0.01            |
| 4          | 85%    | 14.98       | 0.02            |
| 5          | 85%    | 14.97       | 0.03            |
| 6          | 85%    | 14.96       | 0.04            |

3. Result and Discussion

3.1 Bending Strength Test

'Figure 3'. Show the relationship between the bending strength and different ratios of reinforcement of composites and nanocomposites. Results prove the bending strength increases after adding of PA6 nanofibers, it is arise from 2 MPa for UPS to 14.5 MPa for UPS reinforced by (14.96 + 0.04)% wt.% of (GF+PA6 nanofibers) respectively. This is because transfer of composites behaviour from brittle to ductile materials which leads to more toughness of these nanocomposites. This is agreement with Cristina M. et.al [9]

![Figure 3: Bending strength of Nanocomposites with Deferent Ratios of a Reinforcement Material](image)

3.2 Density

'Figure 4'. Show the density of composites under deferent ratios of reinforcement materials as in table 2. Density Results refers to increase of microcomposite density with adding the glass fibers with ratio 15% wt.%, this is because the glass fibers have more density than unsaturated polyester according to the rule of mixture of composites.

On the other hand, the density decreases after adding the PA 6 nanofibers, and it continue with decreasing by increasing of PA6 nanofibers weight ratio. It decreases from 1.5 g/cm3 with (0 wt%) of PA6 nanofibers to 1.01 g/cm3 with (0.04 ) wt.% of PA6 nanofibers. This is because the nanofibers is merged significantly with matrix material [10-11]
3.3 Impact strength Test

‘Figure 5.’ Show the relationship between the impact strength and different ratios of reinforcement of composites and nanocomposites. Results prove the impact strength increases after adding of PA6 nanofibers, it is arise from 0.5 MPa for UPS to 1.5 KJ/m² for UPS reinforced by (14.96 + 0.04)% wt.% of (GF+PA6 nanofibers) respectively. This is because Polymer nanofabric interleaving increased the threshold impact force (the force to cause initiation of impact damage) [13-15]

3.4 Weight loss Test

‘Figure 6’. Show the relationship between the weight loss of composites and nanocomposites with different ratios of reinforcement materials exposed to H2SO4 acid for 30-40 days with period rate 10 day for each test. Results proved the weight of UPS sample decreases with increasing the immersion time in the acid, this is because the degradation of polymer chain. Also , adding of GF leads to lower weight loss than UPS. This is due to a glass fiber barrier that prevents the acid from reaching the polymer chains and reduces its degradation. While with adding of the PA6 nanofibers leads to more reducing of weight loss of nanocomposites and preventing it from degradation this because it has more homogenous and lower voids . As well as the nanofibers prevent the polymer from degradation by its immersed dramatically in polymer chain this is leads to higher chemical resistance than other samples.[16]
4. Conclusion
We conclude that the adding of PA6 Nanofibers leads to improve the mechanical and chemical properties of nanocomposites, it leads to increasing of impact and bending strength, while it leads to decrease of density. In addition, it leads to enhancement of chemical resistance via H2SO4 acid.

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