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An Investigation Into The Effect Of Carbon Nanotube-Based Nanocomposites On The Electrical Conductivity Of Polyester

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Abstract:

This research has been done by adding functionalized nanocomposites to flock powder (polyester) to increase the electrical conductivity. This method is a simple and cost-effective method, which has been used to activate polyester flock fibers. In the industrial method, to activate (increase the electrical conductivity) of polyester fibers, the method of adding moisture has been used, which has led to the improvement of the electrical conductivity. However, at the laboratory level, the method of adding functionalized nanocomposites to polyester fibers was used. For this purpose, functionalized nanocomposites with different percentages were added to flock powder (polyester fibers) during different processes. In this method, first oxidized nanotubes are synthesized, then surfactants are added and nanocomposites are added to polyester fibers with different percentages. For optimization, parameters such as pH, percentage of increase in operating nanocomposites, sonic time, centrifuge speed, diffraction rate, rate of change in electrical conductivity of polyester fibers were investigated.

Keywords: Carbon Nanotube, Flocking, Nanocomposite, Electrical Conductivity.

Introduction

Carbon nanotubes were first discovered in 1991 by Ijima. Since then, carbon nanotubes have attracted much research for potential applications in a wide range of industries. Carbon nanotubes demonstrate different properties at the nanometer level, which lead to different properties depending on the type of nanotube. Carbon nanotubes are different from other carbons such as graphite, diamond, etc. This is because carbon nanotubes are one-dimensional carbon materials with an aspect ratio greater than 1000 [1].

The aspects ratio of carbon nanotubes is very high because carbon nanotubes are made of thin tubes with a few nanometers in diameters but are also a few microns long. Higher aspect ratios possess exceptional mechanical, thermal, and electrical properties on carbon nanotubes that make them the reinforcement elements in various polymers for the production of nanocomposites. Agnihotri et al. found that even if carbon nanotubes have excellent mechanical properties, their combination in polymer matrices does not necessarily lead to fully improved nanocomposites. They found that tensile strength and modulus are increasing with increased filler material.

Recently, carbon nanotubes based on polymeric materials have been presented. This is because carbon / polymer nanotube nanocomposites can be applied in various fields, including heat resistance, chemical sensing, electrical and thermal resistance, electromagnetic absorption, energy storage performance, etc.

Carbon nanotubes that grow on carbon liquids are then embedded in a polymer matrix, representing fewer dispersion problems than polymer carbon nanotubes. However, the effect of their processing parameters on the thermodynamic and surface properties of these composites has not been fully assessed. It should be noted that the quality of carbon nanotubes produced depends on many factors such as growth time [2-3], catalyst and growth temperature, etc. [4]. The composite properties can be optimized simply by changing the reaction time in the chemical vapor deposition reactor. The substrate for the preparation of the polyester resin acid coating bath includes nickel sulfate ($NiSO4.6H2O$), sodium hypophosphite ($NaH2PO4.H2O$), sodium succinate ($Na2C2H4O4.6H2O$), and succinate acid ($C4H6O4$) is used for the growth of carbon nanotubes.

If the growth time on the carbon surface containing carbon nanotubes is about 5 minutes, not much growth is observed. Since the growth time increases to 10 minutes, the presence of carbon nanotubes is observed on the surface. However, the density of carbon nanotubes is very low. The length of the observed carbon nanotubes is 4-5 micrometers [5]. When the growth time increases to 15 minutes, the density of carbon nanotubes changes, and the length of these samples also increases to 10 µm. A better and more uniform carbon surface can be observed when the growth time increases to 25 minutes [5]. It can be found that the length and density of carbon nanotubes on the carbon surface enhanced with increasing time.

Well dispersion of carbon nanotubes within the different matrices is the most important point in making nanocomposites [6]. Selecting the most appropriate steps in terms of compatibility for nanocomposite components, namely carbon nanotubes and unsaturated polyester resin, is technologically effective [7]. The initial stage of compatibility means reducing nanotube interactions and bonds. The second stage of adaptation is the uniform distribution of particles. At this stage, unsaturated polyester shows a significant modification [8]. According to recent research, proper dispersion of carbon nanotubes has been considered through various methods, including modification of the controlled shear surface of carbon nanotubes [9,10]. After surface modification by iron oxide (III), the chemical coating of the multi-walled carbon nanotubes greatly affects the multi-walled carbon nanotubes [11].

The use of surfactant-coated carbon nanotubes has become almost a standard method for various applications. Surfactants such as Cetyltrimethyl ammonium bromide (CTAB) are commonly used during polymerization [12-13]. Electrostatic Flo King is currently the most widely used in the Flo King industry. In this process, for example, the electric charge of flock fibers and the transfer of electrostatic force to the surface of the fluid viscous bed and the adhesive layer can bring the flock fibers to the desired surface. Kleber and Marton created a simple model for the movement of the flock in the flocking area. The results showed that the surface load of flock fibers is not uniform due to the unequal application of the final conductivity and the length of flock fibers. In 2000, HOU measured the Flocking movement in the flocking area. The velocity distribution of moving flock fibers in this study shows that under optimal conditions, flock fibers can have a maximum speed of 1 to 9 m/s [14]. Based on the above, the present study aimed to investigate the effect of carbon nanocomposites based on carbon nanotubes on polyester electrical conductivity.

Materials and Methods

The nanocomposites synthesis in the presence of Cetyltrimethyl ammonium bromide (CTAB) and its absence

Table 1: Determining the optimal amount of nanocomposite added to flock powder (polyester fibers) without CTAB

Determining the optimal amount of nanocomposite added to flock powder (polyester fibers)					No.	
The results of the electrical conductivity test of flock powder (ohm/cm2)	The results of flock powder spray (s)	Nanoparticle percentage(%)	**flock powder (polyester fibers) weight(gr)**	**Nanocomposite weight(gr)**		
66 unacceptabe	33 unacceptabe	0.5	99.5	0.5	without CTAB	1
59 unacceptabe	40 unacceptabe	0.5	99.5	0.5		2
62 unacceptabe	34 unacceptabe	0.5	99.5	0.5		3
68 unacceptabe	37 unacceptabe	1	99	1		4
74 unacceptabe	40 unacceptabe	1	99	1		5
70 unacceptabe	32 unacceptabe	1	99	1		6

As shown in Table (1), after adding the CTAB-free nanocomposite sample to the flock powder, three samples were taken from each of the 0.5 and 1 prepared percentages, and the desired tests were performed on them. After the test was done, all samples had unacceptable results, and the sample was not approved. In the second stage, 0.5 g of nanotubes prepared in CTAB was added to 99.5 g of polyester fibers. The tests performed were better than the initial state of polyester fibers, but the results were not acceptable. In the third stage, 1 g of nanotubes prepared in CTAB was added to 99 g of polyester fibers, and the desired tests were done on the modified flock powder, which was accepted and confirmed. The fourth step was performed in two steps to determine the optimal value. 2 g of nanotube was added to 98 g of flock powder, and 3 g of nanotube was added to 97 g of flock powder.

Table 2: Determining the optimal amount of nanocomposite added to flock powder (polyester fibers) with CTAB

No.	**Determining the optimal amount of nanocomposite added to flock powder (polyester fibers) with CTAB**				
	Nanocomposite weight(gr)	**flock powder (polyester fibers) weight(gr)**	Nanoparticle percentage (%)	The results of flock powder spray (s)	The results of the electrical conductivity test of flock powder (ohm/cm2)

1	with CTAB	0.5	99.5	0.5	35 unacceptable	69 unacceptabe
2		0.5	99.5	0.5	37 unacceptable	59 unacceptabe
3		0.5	99.5	0.5	34 unacceptable	62 unacceptable
4		1	99	1	20 approved	94 approved
5		1	99	1	23 approved	96 approved
6		1	99	1	22 approved	106 approved
7		2	98	2%	28 approved	107 approved
8		2	98	2%	23 approved	110 approved
9		2	98	2%	26 approved	100 approved
10		3	97	3 %	16 approved	108 approved
11		3	97	3 %	20 approved	110 approved
12		3	97	3 %	17 approved	103 approved

As shown in Table (2), after adding the CTAB-free nanocomposite sample to the flock powder, three samples were taken from each of the 0.5 and 1, and 2 and 3 prepared percentages, and the desired tests were performed. After the test was done on all samples, the results of 0.5% sample were unacceptable, and the sample was not confirmed. Nevertheless, when the percentage of nanocomposite was increased, the test results were accepted according to the ASTM D3597 standard, and the samples were approved.

In this study, the flock movement measurement test measures the ability to increase and disperse flock fibers in the electrostatic field. For this purpose, 2 gr of flock powder (polyester fibers) is weighed with a precise scale, and according to the figure, it is placed on a small metal plate as an electrostatic test plate in the test room, and then the direct current voltage amounted 40 kW per 2 g of flock fibers was applied by an electric field on a metal plate. The flock fibers activity is determined after applying an electric field per second, then the activity fibers movement per second is recorded in the electrostatic field. The flock powder sprayer device must be set to the guide number of 40 kOHM as shown in Fig (1), then we press the start button, and after a maximum of 30 seconds, we press the stop button and control the spread of flock powder.

Fig1: Setting the device to 40 kV

Flock powder should be spread evenly on a special plate for a maximum of 30 seconds. The acceptance criterion for this test is determined visually; the reason for scattering is due to the charge of the fibers. If the particles do not have enough electric charge, the scattering rate is low, or the sample does not scatter on the screen at all. A circular electrode is used to determine the flock conductivity. In order to measure the flock conductivity, 100 g of flock powder is spread on a perfectly smooth and non-conductive surface such as glass, and the conductivity is measured from several points on the spread surface. The electrode is directly placed on the flock powder without any pressure, and then the conductivity is read. The electrically charged flock fibers should show conductivity between 90 and 110 Ohm/cm2 as soon as the electrode is placed directly on the flock without pressure.

Findings

As shown in Fig (2), the nanocomposite-modified flock powder is uniformly distributed on the plate surface in less than 30 seconds, indicating that the polyester fibers have sufficient electrical charge; nanocomposites have increased the particles electrical conductivity. In contrast, as shown in Fig(3), the flock powder did not spread on the plate surface for more than 30 seconds, indicating that the sample had no electric charge.

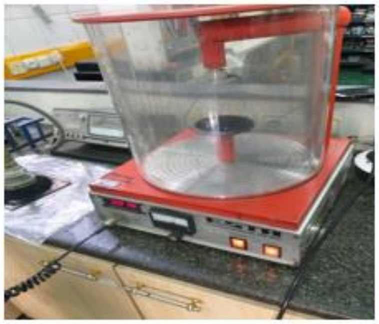

Fig 2: Nano-composite flock sample spraying test, Fig 3: Flock sample spraying test alone

The flock spraying tests (without CTAB) showed that the samples had no acceptable spray at times higher than 30 seconds. Also, the results of flock spraying tests (with CTAB) showed that the samples had acceptable spraying in less than 30 seconds.

Fig 4: View of the electrical conductivity of flock fibers

Fig 5: Images related to the electrical conductivity test of raw flock powder

Fig 6: Images related to the electrical conductivity test of modified flock powder

The device for measuring the electrical conductivity of flock powder showed that after placing the electrode, the device showed the number 110 ohm/cm2, which indicates that the fibers have sufficient electrical charge. However, in the case of the raw flock sample, as shown in Figure (4b), after placing the electrode, the device showed the number 40 ohm/cm2 without any change, and this shows that the flock sample has no electric charge.

Conclusion

In this research, the electrical conductivity of flock powder (polyester fibers was increased by adding nanoparticles. In the automotive industry, flock powder is used for car sealing parts such as internal and external dust collectors, internal and external seals, car glass coil circumference, etc. Due to the importance of these materials in the production industry, their production properties are of special importance. One of the desired characteristics is moisture; the geometric shape and size of the fibers also greatly impact the production process. The electrical conductivity of these materials is very important in the production process of auto parts. In this method, nanoparticles were used, and the results were favorable. One of the advantages of this method is the low percentage of nanoparticles, the ease of its implementation, and a significant increase in the electrical conductivity of flock powder. In addition, the nanoparticles did not adversely affect the other properties of flock powder.

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