

A REVIEW ON MWCNTS: THE EFFECT OF ITS ADDITION ON THE POLYMER MATRIX

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Abstract

In recent years, it has been realized that nanocomposite materials are candidates for many applications in all fields due to their unique properties. This review aims to study the possibility of modifying some properties of polymers by adding carbon nanotubes to improve their properties by taking advantage of the large surface area of MWCNTs to volume ratio. For this purpose, multi-walled carbon nanotubes were used at different ratios and by different mixing methods. Then the effect of this addition was monitored by the procedure of some mechanical, electrical and thermal measurements of the resulting nanocomposite materials. The results of the tests showed that the quality of the filling depends on the way it is distributed within the polymer matrix, where the homogeneous dispersion of MWCNTs will reflect on the properties of the nanocomposite material thus benefit from the special properties of it. Also, the results showed that the addition of MWCNTs at low ratios achieved uniform distribution and dispersion, so improved the properties of the materials such as tensile strength, elongation at break and young's modulus. The ratio of 0.5 wt % of MWCNTs represented an average value for adding MWCNTs to various types of polymers. These composite nanomaterials can replace other industrial materials in many applications.

1. Introduction

Many modern technologies and industries need materials that have a mixture of unusual properties which cannot be found in traditional materials such as metal alloys and ceramics. Making materials with special specifications that meet certain design needs have attracted the interest of engineers for many years. For example, aircraft engineers are constantly looking for structures of materials that have a low density, but they are strong, solid, resistant to shocks, abrasion, are not easily eroded, and this integration of qualities cannot be easily collected, as often the materials with strength have a relatively high density, and the increase in strength and hardness leads to a decrease in the impact strength [1].

Composite materials have properties that are suitable for many industrial applications, so they have attained an important position between the various engineering materials, as they combine the properties of two or more materials, passing the disadvantages of each material. In addition, it has the ability to control its properties, whether through their type and ratio of their component materials

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or through their design and manufacturing methods. These materials are divided into three sections: polymer-based materials, metal-based materials and ceramic-based materials [1, 3, 4].

Polymer-based composites are among the oldest advanced composite materials used for various industrial applications such as aircraft, automobiles, ships and radars, because of their low cost, high strength, and stiffness to weight ratio comparing to metallic alloys, in addition to high electrical isolation and very good resistance to corrosion and chemical attacks. Polymeric-matrix composite can be classified in many ways, according to matrix type (thermosets and thermoplastic composites), according to reinforcing material shape (fiber-reinforced polymer and particle-reinforced polymer composites and nanocomposites), or according to the type of fibers (natural fibers composites and synthetic fibers composites) [1, 4, 5]. A nanocomposite is a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nm, or structure having nano-scale repeat distance between the different phases that make up the material [6].

Nanocomposites differ from traditional composites due to their high aspect ratio which leads to the difference in structure thus the properties, where the material behaves differently from its state when it is normal size [6,7, 8]. The properties of the matrix material are greatly affected in the reinforcement. They offer improved hardness without affecting either the toughness or optical clarity. The reinforcing material can consist of fibers (like carbon nanotubes), particles (like metals) or sheets (like clay) [9].

Nanocomposites can be classified according to the presence or absence of a polymeric material in the compound. The first classification is called non-polymeric nanocomposites that do not contain any polymers or polymer-derived materials in their structure, also known as inorganic nanocomposites. There are three types of this group: metal nanocomposites, ceramic nanocomposites, and ceramic ceramic nanocomposites. The second classification is polymeric nanocomposites, which allow polymers to be reinforced at the molecular phase, thus better improvement recyclability, chemical resistance, thermal stability, electrical conductivity, mechanical properties, in addition to low permeability of gases and water, reduce smoke generations and flame obstruction. However, the effect of filler depends on several factors, such as properties of the polymer matrix, nature and type of nanofiller, concentration of the filler in the matrix, filler aspect ratio, filler orientation and filler distribution [3,7,8,10,11].

Polymer nanocomposites can be produced in three methods which are in situ polymerization, solution and molten blending. An appropriate method is selected according to the type of polymeric matrix and nanofiller and the desired properties of the final products [7,8,11, 12, 13,20, 26].

In 1991, a new phenomenon was discovered for the first time, which is called nanotubes, in the NEC Electronic Industries Company in Japan by the scientist Iijima [7, 15, 16, 17] when he was studying the ash resulting from the electric discharge process between two carbon electrodes by using a highly efficient electron microscope. As a result, he found that the carbon molecules take a tube-like arrangement inside.

Carbon nanotubes show a unique combination of hardness, strength and lightness compared to other materials, which usually lack one or more of these properties. They have a very high thermal and electrical conductivity, compared to other conductive materials. Their hardness is equal to the hardness of the strongest material, also they are characterized by tensile resistance which is stronger than iron. In addition, they have a shock-bearing capacity which is stronger than steel. All these amazing features make them an undisputed favorite in many industries and applications [3,7,8,9,15,17, 18,19].

All types of carbon nanotubes consist of carbon, but they differ in length, thickness, and the number of layers, which changes their properties. Depending on these differences, sometimes they behave like metals, and sometimes like semiconductors. It is worth noting that graphene is classified as a form of carbon. The diameter of carbon nanotubes usually ranges from 1 nm to 50 nm, and the length ranges from several micrometers to several centimeters according to the current developments in the manufacture of carbon nanotubes. Carbon nanotubes can be classified

according to their structures into two types: Single-walled carbon nanotubes and multi-walled carbon nanotubes [19, 20, 21,22,23].

The methods of creating carbon nanotubes affect their physical and chemical properties. There are three main methods available to produce carbon nanotubes, arc discharge, laser ablation of graphite, and chemical vapor deposition (CVD) [6,8, 17, 19, 22, 24,25,26,27]

This review covers the effect of carbon nanotubes especially multi-walled carbon nanotubes on the different properties of the polymer matrix, thus gives an overview of how CNTs can be used to improve many applications.

2. Literature review

2.1 The effect of adding MWCNTs on the properties of polymeric materials

Patrizia Savi et al. used ultra-turret, to mix MWCNTs with epoxy resin. After that, a low-viscosity liquid was added, next, the composite solution was placed in a silicone mold for polymerization process to occur in the air. As a result of the occurrence of interfacial polarization and electron transfer resulting from the existence of a conductive network, the energy was dissipated. By reducing the degree of reflection at 6 GHz due to the high interfacial polarization of MWCNTs caused by high aspect ratio and limit surface area. So, it can be used in microwave absorption applications [28].

Because of the presence of covalent bonds, Chunying Min et. al. mixed one-dimensional multi walled carbon nanotubes with two-dimensional graphene oxide by using hydrothermal reaction, Then, sodium hydroxide (NaOH) was added to the solution after cerium dioxide (CeO₂) was distributed homogeneously on both GO and MWCNTs. Finally, the resulting compounds were washed and dried. Where at 1 % of weight, the addition of the MWCNTs achieved a high resistance to friction thus improved the tribological properties of lubricating oils [29].

In addition, MWCNTs can be used to adsorb gold from alkaline and acidic media by precipitating gold on MWCNTs and it does not take long time to fully absorb the amount, as the gold is converted into gold nanoparticles [30].

Moreover, nanomaterials also had an effect on the thermal and chemical properties when the chemically reduced graphene was mixed with natural rubber (NR) using latex method. After that the mixture was vulcanized, then placed on glass panes and left to dry at room temperature. The existence of graphene led to an increase in the surface area thus increasing the storage modulus. Also, increasing the ratio of graphene in NR improved both the thermal and electrical conductivity [31].

Furthermore, to find out the effect of MWCNTs on the mechanical properties of natural rubber (NR), H. Ismail et. al. mixed NR by using two roll mill, before adding carbon black (CB), then MWCNTs were added to the resulting mixture. With the increase in the loading ratio of MWCNTs to become NR=CB=MWCNT, the twist increased. Also, it led to thermal stability at the same ratio, but this increase caused a decrease in the processing and burning time. It was found that both dispersion and interaction were good between CB and MWCNT in the natural rubber matrix at a loading ratio of CB = 29.5wt %, MWCNT=0.5wt %. So, with the presence MWCNTs, the tensile strength, elongation at break, and fatigue life increased [32].

C. Poornima et. al. studied the corrosion resistance of the pre-processed polypropylene granules (PP) by mixing with MWCNTs-COOH via using injection molding to produce the test samples [33]. While R. Ashok Gandhi et. al. dried both PP and MWCNTs, then their granules were mixed by using a twin-screw extruder [42]. In both cases, the increase in the concentration of MWCNTs in the PP matrix increased the corrosion resistance of it [33, 34].

Also, Salih Hakan Yetgin et al. created PP/MWCNTs composite in two stages, where MWCNTs were dried and then mixed with PP by using twin screw extruder. Next, an injection machine was used to manufacture the test samples. Adding MWCNTs even the ratio 0.3 wt% resulted in an increase in

the mechanical properties such as bending strength, tensile resistance and a decrease in both impact strength and elongation at break due to the good dispersion of MWCNTs in the polymer matrix, after this ratio the improvement was slight. In addition, the presence of MWCNTs reduced creep and relaxation rate compared to their absence. Also, increasing the ratio of MWCNTs improved the thermal properties as the crystallization peak and temperatures increased while the storage and loss modulus decreased [35].

To study the mechanical properties of the polymer matrix after adding MWCNTs, C. P. Rejisha et. al. mixed polybutylene terephthalate/polycarbonate (PBT/PC) at different concentrations, then mixed them with MWCNTs by using a twin screw extruder. Finally, the injection molding machine is used to make the test samples. The addition of MWCNTs led to an increase in the tensile strength, impact strength, tensile and bending modules of the nanocomposite. This effect was the highest when adding 0.3 wt % of MWCNTs. Although the increase in the addition of MWCNTs to the mixture resulted in a decrease in the mechanical properties, they remained better than without it [36].

Direct mixing was used to mix MWCNTs with polyethylene glycol (PEG), then put the mixture into epoxy (EP). After stirring and adding a hardener to the mixture, it was left to dry. As a result of adding MWCNTs and dispersing them well inside the composite, an improvement was achieved in both mechanical properties and thermal stability, as the tensile strength and elongation increased [37].

In addition, Nadia A. et. al. mixed two solutions, one of them contains polymethyl methacrylate (PMMA) and the other contains MWCNTs, by a direct mixing method, then the nanocomposite was put in the oven to ensure removal of the solvent. The ratio 0.5 wt% of MWCNTs achieved an improvement in hardness, tensile strength, tear strength, fracture energy, elongation, and impact strength. It also achieved an improvement in the electrical and thermal conductivity of the composite [38].

Ethylene-co-vinyl acetate-co-carbon monoxide (EVACO) was melted in DCM, with continuous stirring. The fillers were added to it slowly. Next, the compound was mixed well by strong stirring and ultrasound. Finally, the compound is left to dry at room temperature. The lower ratio of MWCNTs led to increase in the tensile strength compared with using larger rates of other nanofillers to obtain the same result, thus increase in the crystallization ability. Also, increasing ratios of MWCNTs resulted in decrease in the mechanical properties due to their presence as agglomerates inside the compound [39].

Ali Shabani et. al. dried both polyamide-6 (PA-6) and styrene-acrylonitrile (SAN) before mixing with MWCNTs. Then, these materials were mixed in three different approaches, which are as follows: the first approach, PA-6, SAN and MWCNT were mixed and added to the extruder at the same time. The second approach, firstly, PA/MWCNT was mixed and fed to the extruder, then SAN was added. As for the third approach, PA/SAN was mixed and fed to the extruder, then MWCNT was added. Adding MWCNTs, even in low ratios, improved the tensile strength, impact strength and young's modulus, especially at the concentration of 0.5 wt % although the mixing protocol is different. Where the second mixing method gave a better improvement in the mechanical properties [40].

Also, when using a high shear mixer (IDMX) connected to injection molding machine to blend MWCNTs with polycarbonate-ABS and form the composite, this method achieved a homogeneous distribution of MWCNTs within the polymer matrix, thus improvement in the mechanical properties of the composite [41].

2.2 Effect of modifying MWCNTs before addition to polymeric materials

Wenzhong Ma et. al. [42] used reversible addition fragmentation chain transfer (RAFT) and the click reaction for azide-terminated poly methyl methacrylate (PMMA) polymerization. Before adding to MWCNTs, the mixture consisting of MWCNTs-g-PMMA was processed by ultrasonic for half an hour, then CuBr solution was added. Next, the mixture was placed in an oil bath at 50°C after replacing the gas with nitrogen. After finishing the click conjunction, the composite was filtered with ethylene diamine tetra acetic acid, and ethanol centrifugation was applied. Finally, unreacted PMMA was removed and dried. It was observed that by increasing the reaction time, the kinetic reaction

rate increased in PMMA-g- MWCNTs even at 50 °C. This happened quickly in less than 24 hours, after this period, there was no remarkable change. Also, the maximum grafting rate the compound could reach was 21.9 %. It was also noted that the diameters of MWCNTs in PMMA-g- MWCNTs are larger than the pure MWCNTs, which indicates a successful distribution of PMMA on their surface.

Furthermore, Boggarapu Praphulla Chandra et. al. used carboxylated and octadecyl amine functionalized MWCNTs to do a carbon-carbon coupling reaction in dimethyl formamide and toluene, then the nano palladium (Pd) was deposited on them by microwave-induced reaction. Finally, p-MWCNT-Pd and np-MWCNT-Pd were obtained. The presence of CNTs led to the use of a small amount of active catalyst and thus obtained faster reactions and high production, so a very high catalytic activity. Also, there was no change in the shape of the tubes either after acid treatment or hybrid formation. However, it was found that the carbon nanotubes are covered with metallic nanoparticles. Therefore, the polarity of the functional shape plays an important role, so the best reaction conditions are with DMF as solvent, while in p-MWCNT-Pd showed better performance in polar DMF, and np -MWCNT-Pd achieved more effective in toluene [43].

Chao Liu et. al. ground both carbon blacks (CB) and multi-walled carbon nanotubes (MWCNTs) after being modified with ionic liquids by using an agate mortar. Then, they mixed them with silicone rubber (SR) via using a two-cylinder mill. Finally, polyolefin elastomer (POE) and 2,5-dimethyl-2,5-di(tert-butylper-oxy)-hexane (DBPH) were added by melting and hot pressing, then they did vulcanization and drying to obtain the final mixture. Better dispersion of MWCNTs was achieved due to both of the large length and high surface area of it, thus reduced agglomeration. The interactions between MWCNTs and ionic liquids (IL) were stronger than those of carbon black for the same reason. Moreover, the addition of MWCNTs resulted an increase in viscosity and a decrease in the volume fraction of the SR phase. Thus, these conductive networks had a role in reflecting, scattering and absorbing the incident radiation. Therefore, they can be used to remove electromagnetic pollution [44].

Moreover, to remove nonylphenol (NP) from the samples Yung Dun Dai et. al. used a cellulose acetate film to filter NP of water, where the pH of all samples was set to 4. Then, MWCNTs treated with nitric acid (HNO_3) were used. As a result of this treatment, there was a change in their properties (increasing the surface area, average pore diameter and pore size) thus increasing their ability to absorb NP, where the absorption was high in the beginning then decreased over time. This is due to the presence of a lot of free surfaces available on MWCNTs initially and decreasing with time. Therefore, it is endothermic absorption and depends on the temperature of the solution [45].

After modifying the MWCNTs to become a magnetic core, Xiaodong Huang et al. mixed it with iron oxide (Fe_3O_4), thereafter the composite was dried for a day. Thus, MWCNTs became magnetic core in magnetic multiwalled carbon nanotubes M-M-ZIF-67. Due to the presence of a lot of porous and magnetic surfaces on MWCNTs, this modification led to the possibility of absorption nine organic chlorine insecticides (OCPs) from agricultural irrigation water samples [46].

Also, multi walled carbon nanotubes, after oxidation with different amounts of carboxylate to form carboxylated carbon nanotubes (F-CNTs), were added to the drug during anti-solvent precipitation of hydrophobic drugs. Despite the combination of F- CNTs into the drug, it did not lead to a change in the crystallization, meaning the melting point remained the same. But the solubility percentage increased with the decrease in the percentage of carboxylate. Also, the time needed to dissolve was decreased thus, the rate of dissolution of hydrophobic drugs can be controlled [47].

Single wall carbon nanotubes (SWCNTs) and natural rubber (NR) were dispersed for two hours after being dissolved in toluene with ultrasonication. The next step, vulcanized the mixture and mixed for an hour before the solvent was evaporated to obtain SWCNT/NR. Where the presence of interfacial adhesion between SWNTs and NR led to transfer of the internal pressure from the polymer to fillers, so the tensile strength of the nanocomposite increases by increasing the ratio of SWNTs [48].

Yonglai Lua et. al. mixed multiwalled carbon nanotube bundles (MWCNTB) with natural rubber (NR) matrix after plasma induced grafting MWCNTB a layer of polyacrylic acid (PAA) by mechanical mixing. Because of pretty growth of MWCNTB, resulted in good surface adhesion between MWCNTB and PAA and good dispersion, thus improved the mechanical properties. It also achieved a reduction in both the dynamic deceleration and the accumulated heat of composite [49].

From another viewpoint, Attila Bata et. al. painted MWCNTs with an inorganic layer of SiO₂-MgO, then mixed with both polyethylene (PE) and PP by using an internal mixer. After that, the samples were prepared by cutting from the resulting products using compression molds in order to know the effect of these MWCNTs on the mechanical properties of the polymer matrix. The inter bonding between the inorganic coating and MWCNTs resulted in a homogeneous dispersion of MWCNTs within the polymer matrix, where the greater the ratio of MWCNTs in the coating was, the more homogeneous dispersion of MWCNTs and distribution within the polymers became. So, this led to improvement of the mechanical properties of the matrix such as tensile strength, elongation and impact strength [50].

Also, Prashant Jindal et. al. suspended MWCNTs and PC in chloroform. Then, they were mixed. Next, the preparations were dried and used to prepare the composites by compression moulding. This addition resulted in a significant increase in both the modulus of hardness and elasticity when compared with pure PC even at a low addition ratio of MWCNTs [51].

The melting and crystallization behavior of nylon (polyamide 1010) differed when adding MWCNTs. Hailin Zeng et. al. heated the PA1010 monomer salts after removing air from them before adding carboxylic acid-functionalized MWNTs (MWNT-COOH) to it, then mixed them with strong stirring reacted under vacuum. This blending improved the mechanical properties of the composite, as both the Young's modulus and the storage modulus increases with the increase of the ratio of MWCNTs in the matrix [52].

In addition, Zdenko Š Pital'ský et. al. modified MWCNTs in three methods before adding them to an epoxy amine polymer. Where both the first and second modification were chemical, by modifying the end walled at the ends of MWCNTs, and modifying the side wall of the full length of MWCNTs, while the third modification was physical by coating MWCNTs with polyaniline (PANI) during the polymerization process. Then the solution is placed in the oven for three days. The chemical modification improved the dispersion of MWCNTs in the matrix more than the physical modification. Although, all the modification methods drove to an improvement in the mechanical properties of epoxy amine in addition to an increase in thermal stability. However, the modification in the second method resulted in a greater improvement in the characteristics compared to the other modifications [53].

Whereas Lucía M. Famáa et. al. coated MWCNTs with iodine and starch before adding it to the starch, which is the same type used for packaging, to produce a nanocomposite. The high dispersion of MWCNTs and the strong adhesion between them and the starch led to a significant improvement in the mechanical properties of the nanocomposite such as tensile strength and hardness, even at low ratios of MWCNTs, where the increase in each of them was 35,70 % when adding MWCNTs by 0.055% wt [54].

J.B. Bai et. al. treated MWCNTs in three different ways that affect their length and total volume, after manufacturing it by chemical vapor deposition method. Then each type was added in three different ratios to the epoxy resin. Use of 0.5 wt % of MWCNTs prepared with methanol that was dispersed using magnetic agitation improved the mechanical properties and electrical conductivity of the resulting composite. While MWCNTs prepared by sieve of 0.5 mm under the influence of pressure had a high effect on improving the electrical properties. Also, the treatment by the three methods affected the length of the tubes thus their mechanical and electrical properties, while the treatment had no clear effect on the morphology of the individual nanotubes [55].

K.Z.K. Ahmad et. al. used a mortar and pestle to mix MWCNTs and nanoclay, then the mixture was added to methanol and Liquid Epoxidized Natural Rubber (LENR). Next, introduced into epoxy resin

and a hardener was added, then the resulting mixture was put in a steel mold and left to solidify. Each of the ratio of MWCNTs, nanoclay, pre-cure temperature and cure temperature affected the mechanical properties of the composite as the concentration of MWCNTs had a great influence on the impact strength where it achieved the highest impact strength at the ratio 0.6 wt%, while the cure temperature had a greater effect between other factors on the tensile modulus. However, both the fracture toughness and the strain at fracture were affected by the nanoclay content [56].

Table 1 displays the mixing ratios of CNTs in the previous literature:

Table 1. The Mixing Ratios of CNTs

<i>Type of CNTs</i>	<i>Type of polymer matrix</i>	<i>The ratio of CNTs wt%</i>	<i>Reference</i>
SWCNTs	NR	1, 1.5, 2	48
MWCNTB	NR	4.30 in MWCNTB/ NR. 4.05 in NR/MWCNTB PAA/Si69	49
MWCNTs	NR /CB	0.5, 1, 3, 5	32
MWCNTs- COOH	PP	0.5, 1, 1.5	33
MWCNTs	PP	1, 3, 5, 7	34
MWCNTs covered with (SiO ₂ – MgO)	PP - PE	1	50
MWCNTs	PP	0.1, 0.2, 0.3, 1, 2	35
MWCNTs	PBT / PC	0.15, 0.3, 0.45	36
MWCNTs	PC	0.5, 0.75, 2, 5, 10	51
MWCNTs	EP/ PEG	0.1,0.3,0.5	37
MWNTs	PA1010	1, 2.5, 5, 10, 20, 30	52
MWCNTs	PA-6/SAN	0.5, 1	40
MWCNTs	Epoxy amine	0.5, 1, 5, 10	53
MWCNTs	Starch	0.027, 0.055	54
MWCNTs	PMMA	0.1, 0.3,0.5	38
MWCNTs	Epoxy resin	0.5, 1, 4	55
MWCNTs	Polycarbonate-ABS	1,1.5	41
MWCNTs	Epoxy/Nanoclay	0.2, 0.6, 1.0	56
MWCNTs	EVACO	0, 0.05, 0.1, 0.15, 0.2, 0.25	39

3. Results and Discussion

The treatment of multi-walled carbon nanotubes before adding them as a filler to the polymer matrix affects the final properties of nanocomposite. Figure 1 shows that MWCNTs were treated before the addition to epoxy resin in three different methods. This treatment affected their length, but their direction remained random within the matrix, and did not affect the shape of MWCNTs, therefore the three treatment methods of MWCNTs led to increase in the tensile strength at low ratios. The strongest tensile strength was at 0.5 wt % of MWCNTs, while it decreased at the higher ratios of MWCNTs due to occurrence of agglomeration inside the epoxy matrix [55].

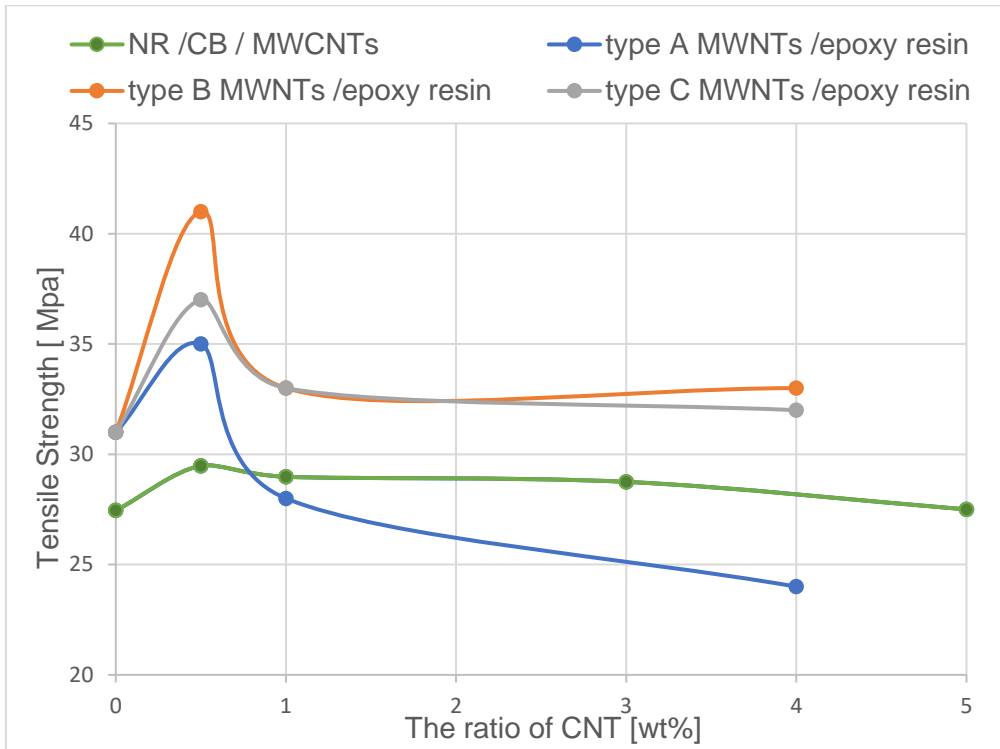


Fig 1. Effect of adding MWCNTs on the tensile strength of the following polymer matrices NR/CB and epoxy resin

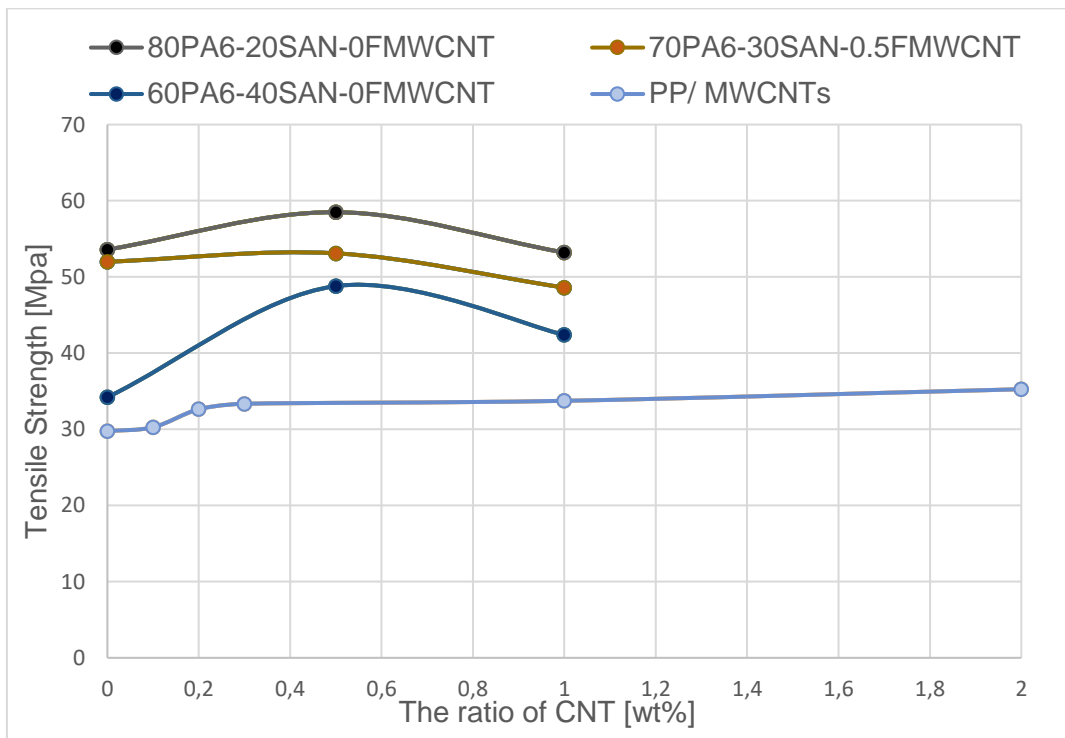


Fig 2. Effect of adding MWCNTs on the tensile strength of the following polymer matrices PA6/ SAN and PP

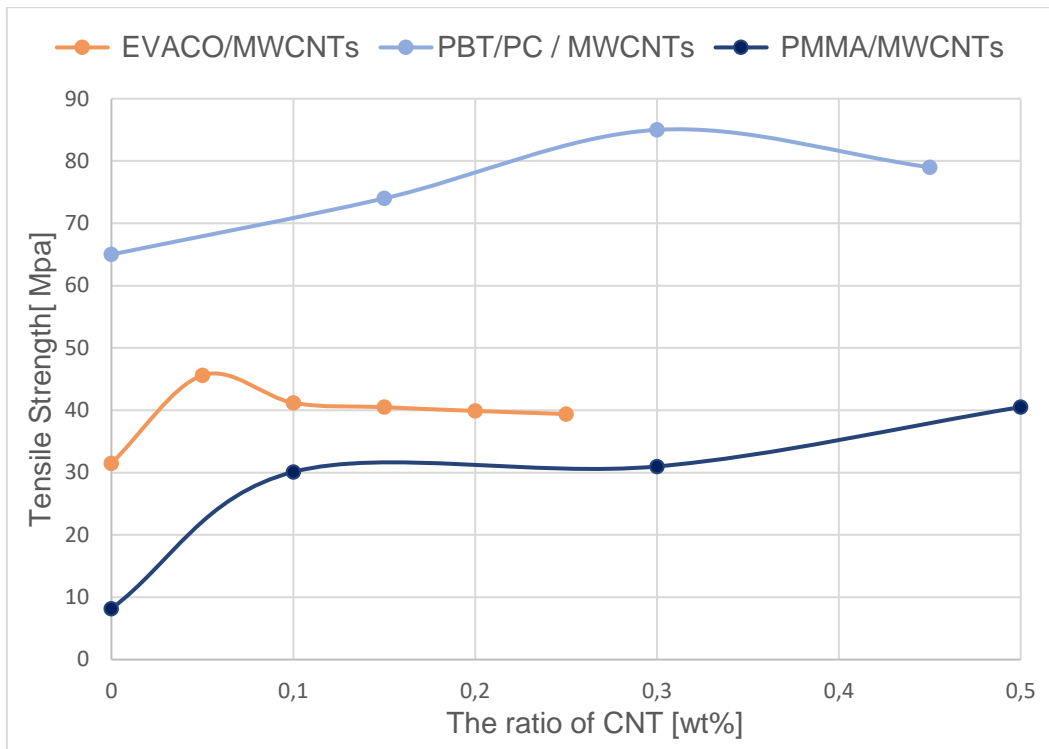


Fig 3. Effect of adding MWCNTs on the tensile strength of the following polymer matrices EVACO, PMMA and PBT/PC.

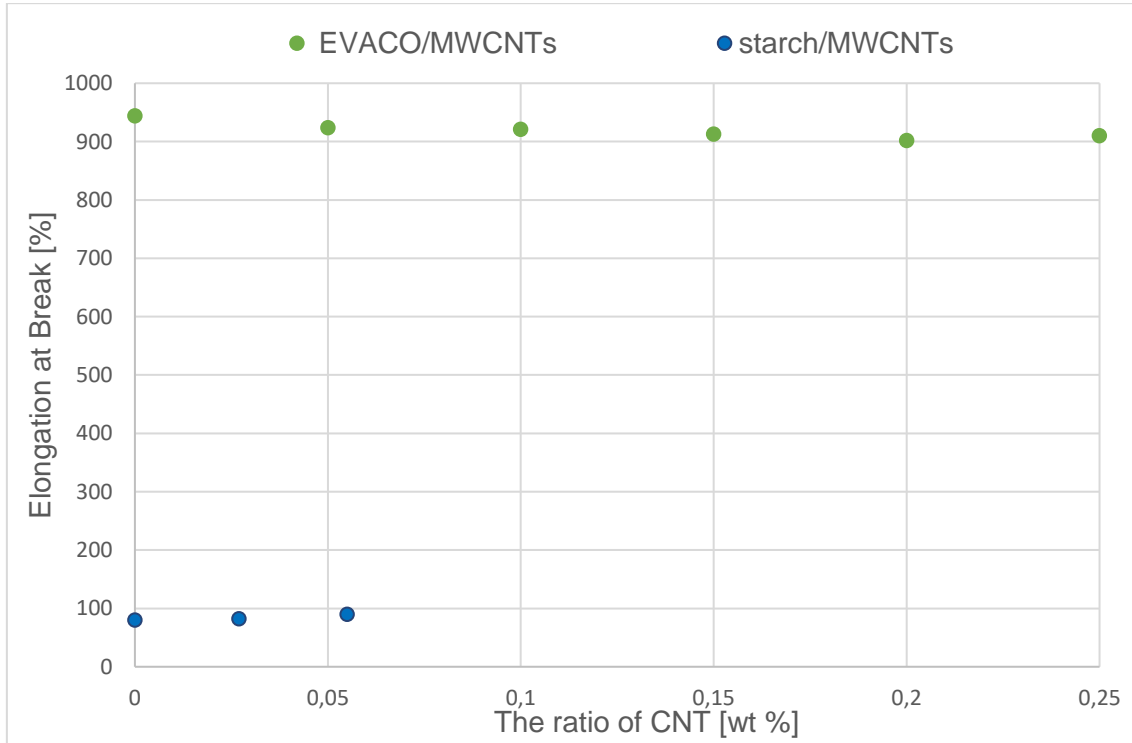


Fig 4. Effect of adding MWCNTs on elongation at break of the following polymer matrices EVACO and starch.

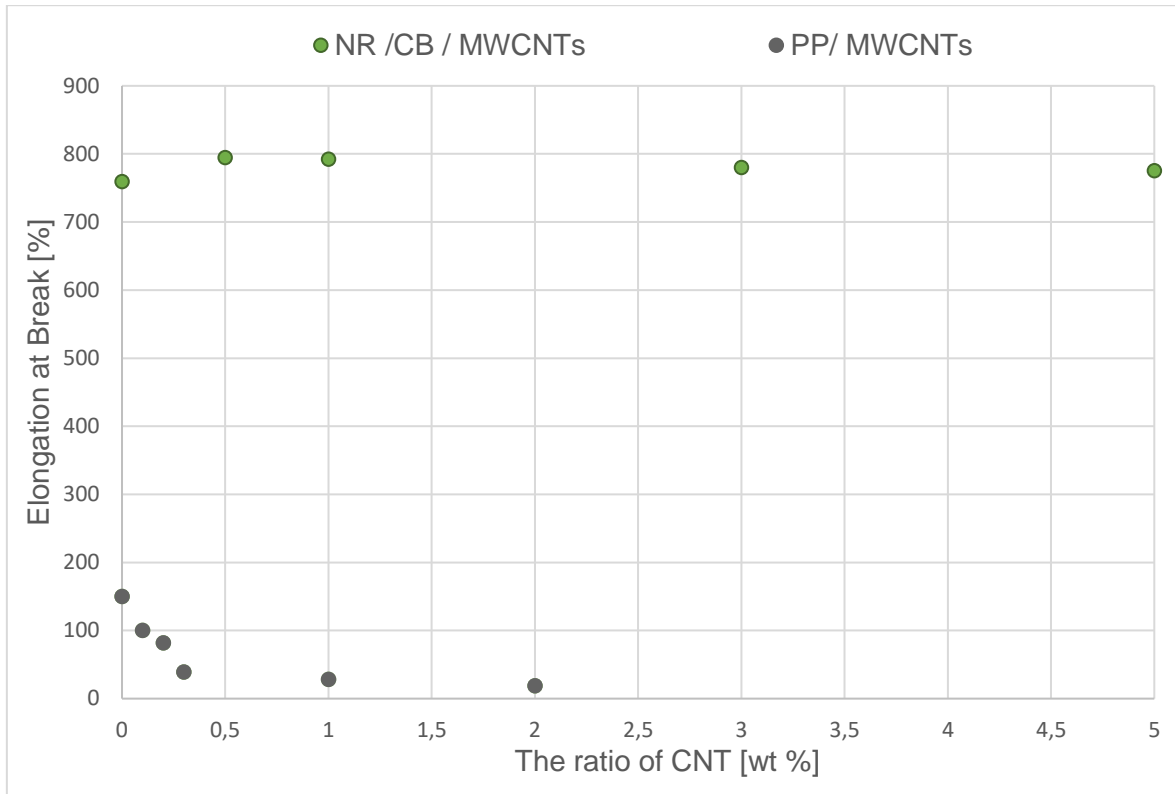


Fig 5. Effect of adding MWCNTs on elongation at break of the following polymer matrices NR/CB and PP.

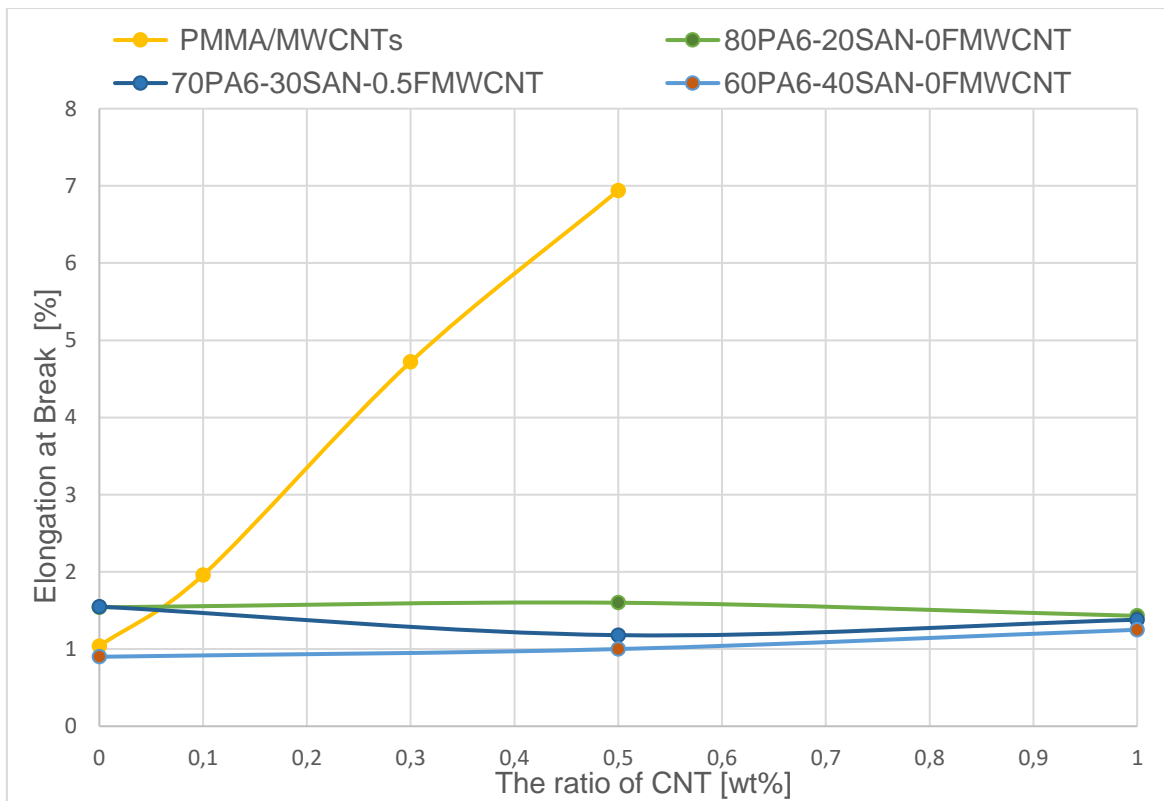


Fig 6. Effect of adding MWCNTs on elongation at break of the following polymer matrices PMMA and PA6/SAN.

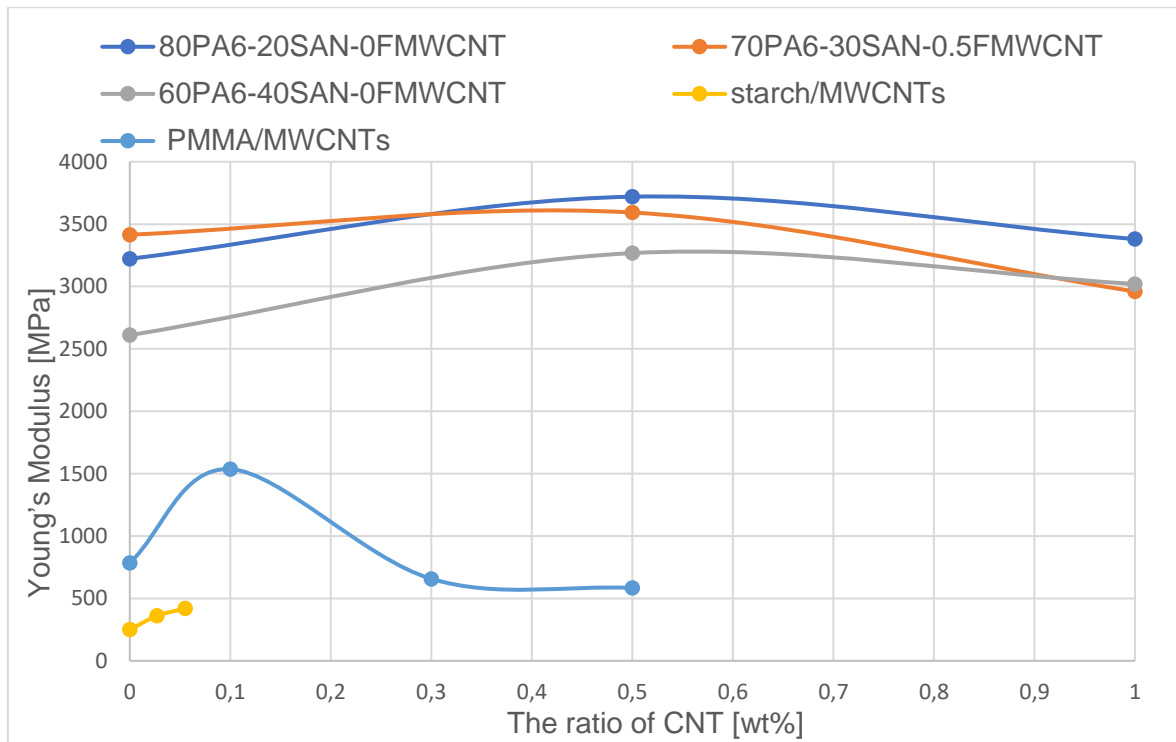


Fig 7. Effect of adding MWCNTs on young's modulus of the following polymer matrices PMMA, starch and PA6/SAN.

In addition, all methods of mixing MWCNTs with PA-6/SAN affected the mechanical properties. But the amount of improvement was different, the tensile strength and young's modulus increased, especially at low concentrations of MWCNTs as shown in Figures 2,7 due to the decrease in the particle size and it resulting in a homogeneous distribution at 0.5 wt %, where it was the best increase in the properties. This means that the addition of MWCNTs at very low rates led to an increase in mechanical properties such as Young's modulus, despite the different ratios of adding other materials (Figure 7). Where addition above this ratio led to lack of adhesion between PA-6/SAN and MWCNTs because of the weakness of the bond between them, thus the decrease in mechanical properties such as tensile strength (Figure 2), elongation at break (Figure 6), and young's modulus (Figure 7). 80PA6-20SAN made the best increase compared to the rest [40].

On the other hand, when the surface of multi-walled carbon nanotubes was modified with carboxyl acid before adding to PMMA, it affected the tensile strength, young's modulus and elongation at break because of the good dispersion and homogeneous distribution of MWCNTs within the matrix as shown in the figures 3,6 and 7. The increased concentration of MWCNTs, increased all of the previous properties except for the elongation at break decreased [46].

Also, as a result of obtaining good dispersion when blending MWCNTs with NR /CB, Figures 1,5 show that by increasing the addition of MWCNTs to NR /CB, the tensile strength and elongation at the break increased up to 0.5 wt% of MWCNTs. After that, the properties decreased however, they remained better compared to the properties of NR /CB without adding MWCNTs [32].

When studying the effect of adding MWCNTs to both PP [35] and PBT / PC [36], this addition helped to improve the mechanical properties of these polymers, as the tensile strength of both PP and PBT / PC increased at low addition ratios of MWCNTs even 0.3 wt %. Then the addition led to a decrease in tensile strength as shown in Figure 2,3. Also, the elongation at break of the PP decreased when MWCNTs were added [35,36] (Figure 5).

Also, adding MWCNTs to the EVACO matrix affected its properties as the elongation at break decreased as shown in Figure 4. While figure 3 shows increase in the tensile strength when adding MWCNTs at relatively low concentrations due to a good dispersion of MWCNTs in it [39].

Figures 4, 7 show that when coating MWCNTs with iodine and starch before adding it to the starch matrix (the same type of starch used in coating), a high dispersion of MWCNTs occurred because of high surface area at very low the ratio (0.055 wt%). Thus, it has an ability to improve mechanical properties and it can be used in several promising applications [54].

4. Conclusions

Manufacturing processes tend to use polymers in large fields instead of metals and other materials. So, these polymers must have suitable properties reinforced with fillers that gain these properties. These fillings are nanomaterials, especially multi-walled carbon nanotubes, because it has unique properties such as high strength, flexibility, high conductivity and thermal stability despite its light weight and small size.

The method of preparing nanocomposites plays a role in affecting their properties, so a homogeneous and uniform dispersion of MWCNTs must be achieved within the polymer matrix.

The results of the measurements showed an improvement in the studied properties in general at low concentration of addition, where adding MWCNTs at 0.5 wt%, improved the mechanical and thermal properties of the polymer. The tensile strength, elongation at break, and young's modulus for most types of polymers increased at this ratio. Although, the different methods of treating them and additions improve the properties, no matter whether the MWCNTs were modified before adding to the polymer matrix or during the mixing method. The results also showed the occurrence of interfacial interactions and the formation of covalent bonds between MWCNTs and the polymer, consequently, a homogeneous dispersion and distribution of them within the matrix. While the addition of MWCNTs high ratios led to agglomerations and a decrease in the interfacial adhesion, it also reduced these enhancements on the properties of the polymers.

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