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Improvement of Mechanical and Physical Property of Polypropylene Nano Composites by the Addition of Multi-walled Carbon Nano Tube

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Abstract: In this study, physical and mechanical properties of polypropylene nanocomposites in the presence of carbon nanotubes (MWCNT) were studied. Nanocomposites were prepared by combining different percentages of MWCNT with PP using melt mixing method. The mechanical and physical properties such as the fracture surface morphology, distribution of CNTs in the material field, the size of the crystals, crystallization and melting temperature, tensile strength, flexural and impact strength and flexural modulus were analyzed. In summary, it was shown that Young's modulus and flexural an increase in the weight of MWCNT, are considerably improved. However, the distribution of the nanotubes was poorer in material terms, the melting temperature has not noticeably changed. Also, the sizes of the crystals in some Miller's pages were decreased. By increasing the amount of MWCNT, an increase in crystallization temperature of PP was observed. Loading 1.5%wt of MWCNT, the amount Tp has increased with about 14.3°C than pure PP. By increasing the MWCNT to 0.4%wt, the mechanical properties were improved. Then changing MWCNT to 0.8%wt, the mechanical properties was reduced.

Keywords: Nano Composite, Polypropylene, Multi-walled Carbon Nano Tube

1. Introduction

Excessive consumption of petroleum-based polymers in packaging and their resistance against micro-organisms has caused the environmental pollutants and the damages caused by them are considered great threat to the environment [1]. Over the past two decades, starch has been the focus of attention as a substitute for oil products in the packaging industry. But the relatively weak mechanical strength starch polymers using these materials are limited to specific applications package. Starch-clay nanocomposites due to high physical and mechanical properties can be substituted for petroleum-based packaging films.

In composites, the properties are that improved in presence of nanomaterials include physical properties such as heat distortion temperature, thermal stability, transparency, and mechanical properties such as tensile, flexural properties and so on. The use of nanocomposites in the preparation of thermoplastic olefins such as propylene, based on the exterior automotive, packaging films nylon, drink bottles stored materials, polymer pipes, wire and cable coatings, etc. is expanding. Recently General Motors produced the first polyolefin nanocomposite parts-PO (clay) for the outer body of 2002 model car which contains only 2.5% inorganic filler is reported. This product contains ten times the stiffness of thermoplastic olefins talc filler and causes 20 percent savings in weight. These parts are used in the outer body of 2002 model car stations. It is estimated that in the US, the widespread use of nanocomposites in vehicles, saving half a billion liters of fuel annually and reduce carbon dioxide emission to the amount of five billion kilograms. Elias and colleagues [2], by examining immiscible polymer blends, polypropylene / polystyrene PP / PS observed that the use of inorganic silica nanoparticles on morphology and viscoelastic properties of the polymer blend different effects.

Rahim [3], the viscoelastic properties of nanocomposites ABS / SiO_2 polymer blends with ABS / PA6 / SiO_2 were examined. They have reported that increasing the percentage of polymer chains and reduce the size of nanoparticles increases the absorption of nanoparticles, increasing entanglement chains and create a three-dimensional network nanopaticles. A survey by Yazdani [4], for adaptation combination PET / PP of modified polypropylene is used by Monomethyl itaconate. Kasagna [5], in a review paper shown that two mechanisms for the formation of solid-like behavior and the effects of the bottom (dependent on the dynamic viscoelastic properties of polymers filled the strain amplitude) in nanocomposites including smoked and spherical silica nanoparticles in similar percentages. Li and colleagues [6], according to the location of TiO_2 particles in the polymer blends PET / PP / TiO_2 concluded that these particles can have different effects on a mixture of two polymers. In addition, many other studies in the Polymer matrixcomposites, fluoropolymer and carbon fiber have been performed [7-10].

2. Materials and Method

Isotactic Polypropylene was Prepare from Bandar Imam Khomeini Petrochemical Complex. Poliran P10800 is the name of commercial samples for granule having density of 0.9g /cm^3 with a melt flow index 8g/10min. Multi-walled carbon nanotubes were prepare by the chemical vapor deposition method with methane carbon source and the metal catalyst, molybdenum and cobalt in the research institute of petroleum industry (Ripi) in Iran. The nanotubes process temperature between 800 to 1000°C. These nanotubes were washed using hydrochloric acid and distilled water and the final purity is up to 95 weight percent. Diameter range was between 1-4 nm and a maximum length of 10 micrometers, without surface active groups. The results of the analysis showed that the best conditions of the BET surface are 290 m^2/gr and the surface of the nanotubes is 500-700 m^2/gr.

Polypropylene and multi-wall carbon nanotubes were dried in a vacuum furnace for 12 hours at 80°C. In this condition, all the moisture levels are likely to be wiped out. Polypropylene granules and the amount of carbon nanotubes (8-25wt %) were mixed together in a beaker for drying. Melt mixing in an internal mixer (600/610 Rheomixer Haake) equipped with dual blades roll is done. Mixing at 180°C with 90 rpm engine speed and mixing time was 15 minutes. Nanocomposite sheet has been produced with pressing nanocomposite mixture between two sheets of Teflon hydraulic press (Test Mini Toyoseiki). In the process of pressing, at 200°C for about 10 minutes and strain about 100 times by two upper and lower hot plate on nanocomposites have been performed. Plates were prepared by cooling inside the presses. In this method, the heater was off the presses and the sample was given time to rest at room temperature for about 5 hours under the pressure of 10 MPa when cooled.

Physical tests performed on the samples. These tests include morphology (the study of brittle failure mode), X-ray diffraction open angle and thermal analysis using Differential scanning calorimetric (DSC). Then the mechanical tests were carried out. These tests include testing the tensile, flexural, and impact.

3. Result and Discussion

3.1. Result of Physical and Mechanical Tests

In this section, we discuss the results of physical and - mechanical tests. SEM and TEM images of carbon nanotubes deposited by methane Sedimentation at a temperature 1000°*c* after the purification stage with different magnifications are shown in Figures 1 and 2.

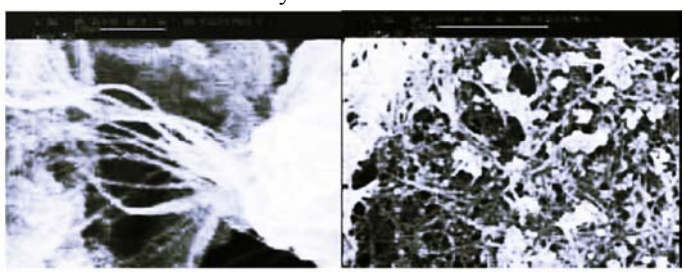

Figure 1. *SEM images of carbon nanotubes at a temperature 1000°c after the purification stage with different magnifications.*

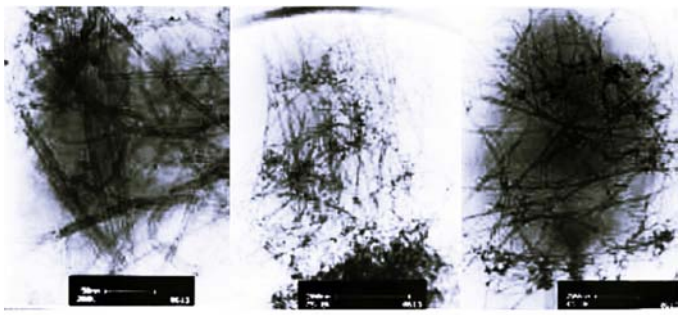

Figure 2. *TEM images of carbon nanotubes at a temperature 1000°c after the purification stage with different magnifications.*

Considering the number of samples, Figures 1-4 are related to surveying the morphology of the Fraction surface of the nano composites with 4.2.1 and 98 weight Percentage of MWCNT are shown by SEM. To better surveying, the morphology of the nano composites two different magnification (1μm and 50μm) is applied in the Pictures.

The white points shows MWCNT Come out of the fraction parts although some assembles are observed for MWCNT %1.

The MWCNT groups are distributed at the bottom of the Polymer matrix (A and B).

Figure 3 (C, D and E) show that increasing in the Loading of MWCNT assembling increases in the background material. So that for the nanocomposite with 8 percent by weight of MWCNT, gatherings of large amounts of MWCNT clearly visible. At higher loads, lack of full dispersive MWCNT and

the cumulative incidence in the matter of context has created unfavorable levels of distribution. The structural defects led to the emergence of stress concentration points and achieve the desired mechanical properties makes it difficult. In some cases levels, focusing MWCNT are very high so that clusters of MWCNT with a diameter of about a micrometer is also visible. But in other areas cannot be seen at all MWCNT. Despite having sheared and high mixing energy during the melt blending process, some accumulation MWCNT remains intact. By comparing samples between 1% and 8% by weight of MWCNT, in the case of the 8% more of the categories of MWCNT accumulate visible. The cluster diameter of MWCNT reduced the mechanical properties of the samples, the results of which will come out in the relevant section.

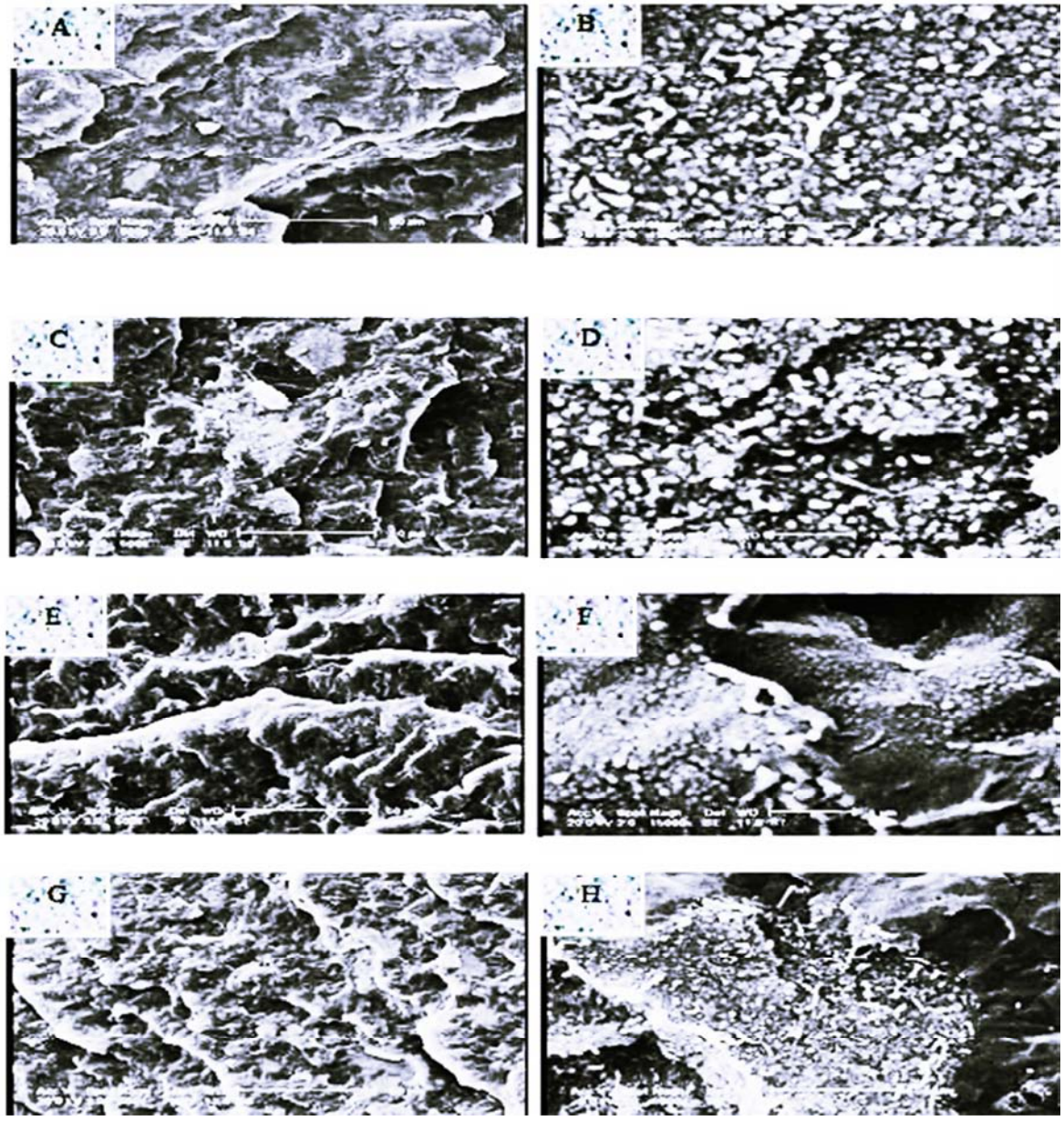

Figure 3. *Images of brittle fracture surface samples nanocomposite, A and B (%1), C and D (2%), E and F (%4) and G and H (%8).*

In Figure 4 two pictures with 5.0% and 8% of MWCNT having magnification of 500nm are shown. As the Images are clear, according to the exposure, surrounded MWCNT in the polymer matrix material, diameter multiwall carbon nanotubes category has grown to more than 50 nm. At 5.0% by weight, the diameter of MWCNT right to 70 nm and in 8% wt. has increased to 54nm.

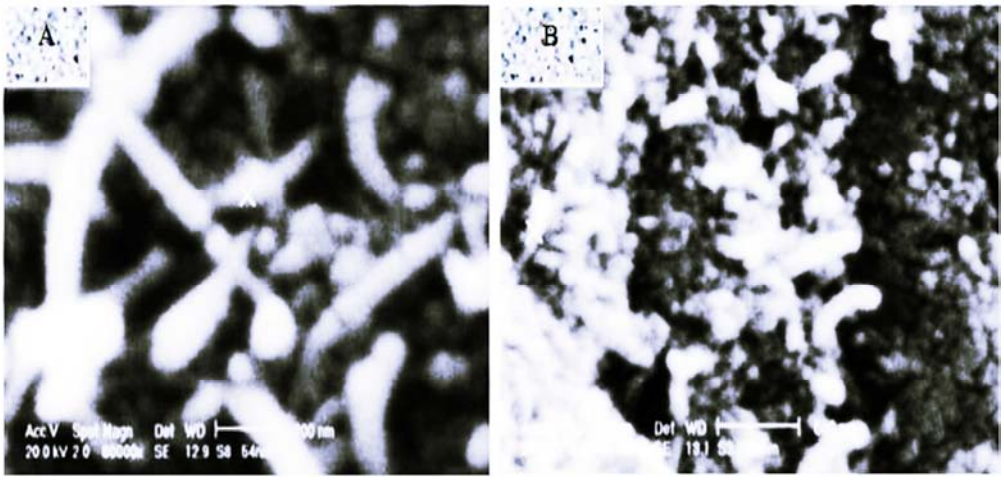

Figure 4. *Fracture surface morphology of the nanocomposites A (0.5%wt) and B (8% wt.).*

Figure 5 shows a TEM image of nano-composite for 0.5% and 1.5%wt. of MWCNT. These images represent a homogeneous distribution of MWCNT with a low percentage in PP. The reason for this low stretch and PP is the MWCNT.

The presented TEM Figure is for nanocomposits with 0.5 and 1.5 MWCNT. The pictures show the homogeneous distribution of Low Percentage MWCNT in pp because there is Low Tensile Strength between MWCNT and pp.

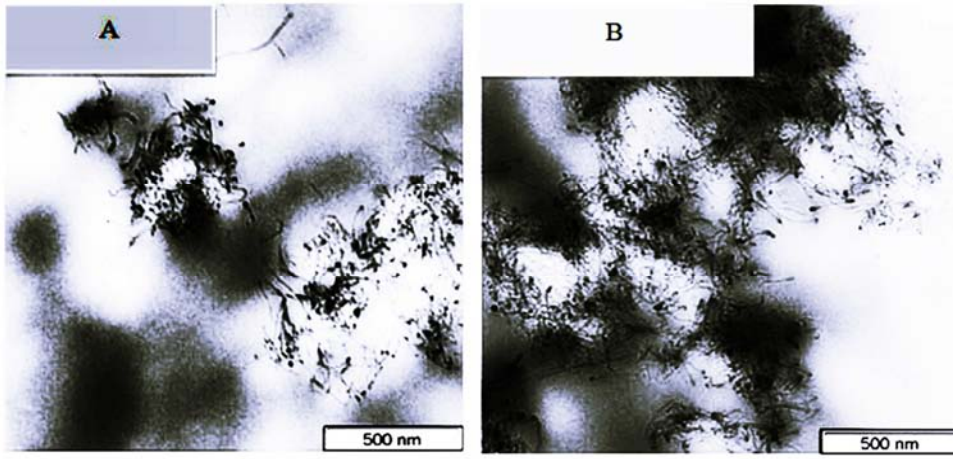

Figure 5. *TEM images A (0.5%wt.) and B (1.5% wt.).*

3.2. Result of Tensile Tests

In this section, the tensile properties obtained from tensile test results are analyzed. The results of the tensile test were shown in Figure 6. As is clear from Table 1, by increasing the percentage of MW NT, the value of elastic modulus also increases. So that by increasing the amount MW NT, from 0% to 4% wt. for NC0 and NC6 respectively, modulus of elasticity increases to 25%.

Table 1. *values obtained from the tensile test for nanocomposite samples PP/MWC NT.*

Sample code	σ_y (Mpa)	E_T (Mpa)	(%at break)	Change modulus with pure (%)	Change the tensile strength of pure sample (%)
NC0	28.3	648	16.75	0	0
NC1	32.07	669	7.37	3.3	12
NC2	21.8	733	4	13	25
NC3	31	752	8	16	9.54
NC4	34.62	766	12.4	18	22
NC5	33.12	781	10.2	21	17
NC6	31.1	811	6.4	25	9.89
NC7	28.15	730	6.4	12.7	5

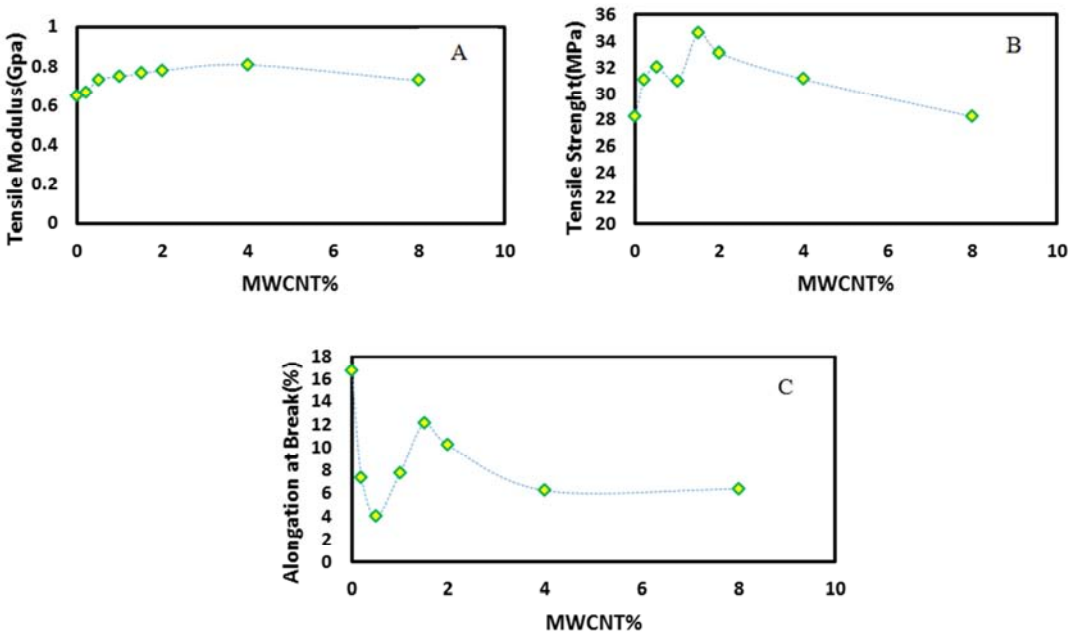

Figure 6. *Changes in tensile properties of nanocomposite PP / MWCNT A (the modulus of elasticity), B (Tensile Strength), C (Elongation at break).*

Figure 6 shown that with Increasing of the amount of MWCNT to %8wt. the Tensile Modulus will significantly decrease. The main reason is because of applying the high level of nanofiller in polymer background. By increasing the percentage of MWC NT in material terms, the bulk nanostructure materials are played in different places of the field. Also by increasing the amount of filler material nanostructures in the polymer matrix, tensile strength usually can be decreased.

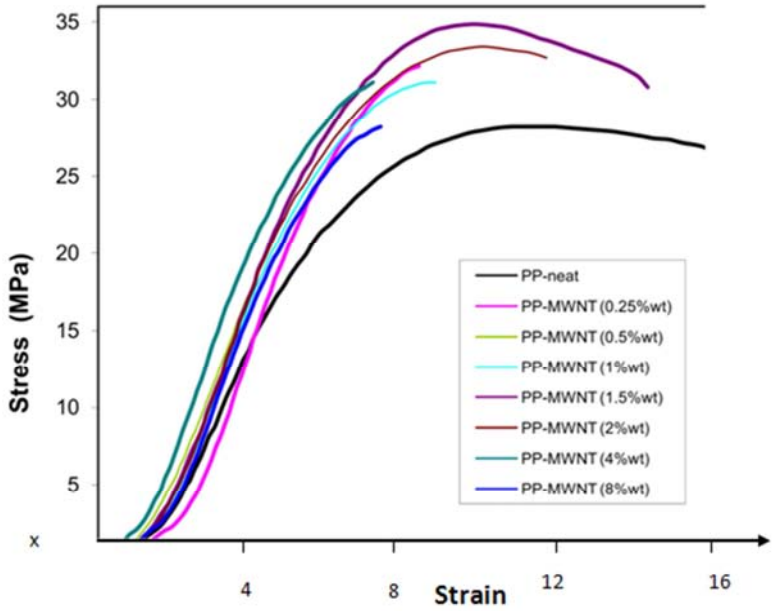

Figure 7. *Stress-strain curve of nanocomposite PP/MW NT.*

Figure 7 shows the stress-strain curves obtained from the tensile test for nanocomposite PP/MCNT is given. According to this figure that by increasing the amount of MWCNT elongation value also declined. Also, the area under the stress-strain diagram declined. According to Figure 7, for example, NC0 yield strength and ultimate strength is obvious. But in other cases (especially the case after NC2) yield strength is the ultimate strength.

The bending test results to come in Figure 8 and Table 2. Experimental results show that both modulus and flexural strength increases with increasing the percentage of nanotubes. These results also show that by increasing the filler loading in background material, in general, significantly increased flexural properties. After NC4, modulus and flexural strength will increase significantly and even reaches 84% in the sample NC6.

Table 2. *Results of bending test samples nanocomposite PP/MWCNT.*

Sample code	σ_{yf} (Mpa)	E_f (Mpa)	F_{max} (N)	Change modulus with pure (%)	Change Flexural Strength than pure sample (%)
0	399	1254	93.5	0	0
0.25	408	1300	87	4	2.25
0.5	418	1396	85.3	11.3	4.8
1	417	1418	88.1	13	4.5
1.5	435	1497	94.6	20	9
2	554	1547	168.6	23	39
4	617	2241	127	79	55
8	629	2304	143.2	84	58

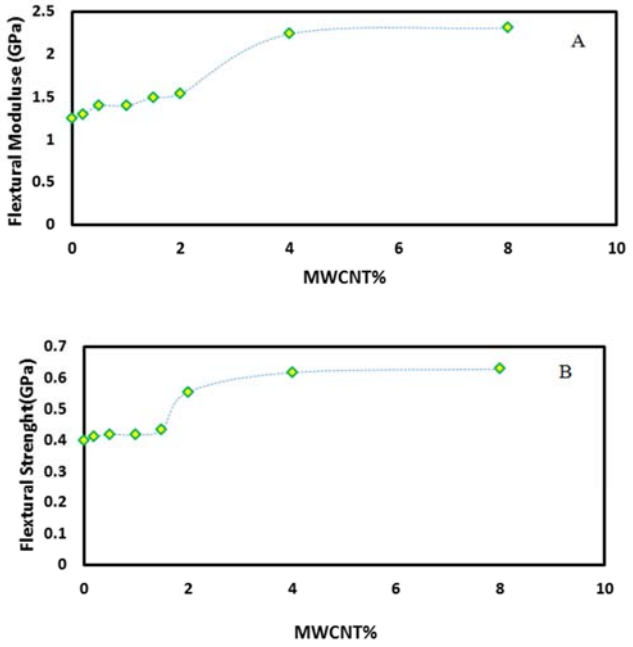

Figure 8. *The curve of the bending test samples (A) modulus, (B) flexural strength.*

The results of the impact test Azodicarbonamide shown in Figure 9.

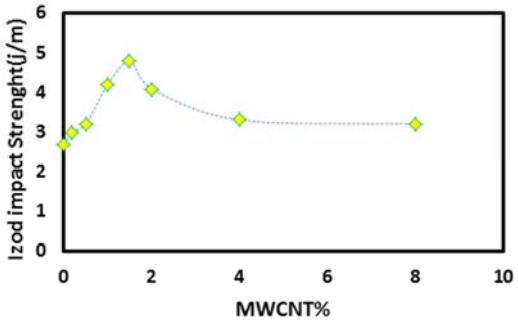

Figure 9. *Chart resistance change for nanocomposites.*

Table 3. *Impact resistance of nanocomposite sample Azodicarbonamide PP / MWCNT*

Sample cod	NC0	NC1	NC2	NC3	NC4	NC5	NC6	NC7
Impact resistance(J/m)	2.7	3	3.2	4.2	4.8	4.1	3.3	3.2

Figure 9 and table 3 shows that with increasing load the MWCNT to 1.5% wt., impact against the resistance have an increasing trend.

So that for NC4 sample, impact resistance has grown about 78%. But by continuing to increase the amount of filler in the matter of context, impact strength decreases. So that in comparison with the 4 NC, NC7 impact strength is reduced by about 33%. Because, by increasing the load MWNCT up to 5.1% by weight, the interface between the field and reinforcing material increases. Therefore, germination growth cracks decrease and increase the impact strength of the samples.

4. Conclusion

In this study, the physical and mechanical behavior of nanocomposites PP / MWCNT were studied. Nano-composite samples were prepared using the proper mixing and then using the hot press, is produced. For distribution of the nanotubes in the polymer material, SEM device was used. It was observed that increasing the percentage of MWCNT nanotubes tend toward Agglomeration. According to the results of the bending test showed that the tensile strength and flexural modulus by increasing the amount of MWCNT to significantly increase that probably because of the influence nanotubes with very high flexural strength and modulus is based on composite samples. Impact strength also increased from the NC0 to NC4 and then with increasing load due to more fragile samples, the impact strength decreases.

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