STUDIES ON THE IMPROVEMENT OF MECHANICAL AND THERMAL PROPERTIES OF NYLON 66 BY USING MULTI-WALLED CARBON NANOTUBES NANO COMPOSITES

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ABSTRACT

The aim of the present work is to improve the mechanical and thermal properties of nylon 66/MWNTs nano composites. Nylon 66 / MWNTs nano composites were prepared through diluting nylon 66 / MWNTs master batch with nylon 66 by melt compounding with a injection molding machine. The effect of MWNTs on mechanical and thermal behaviour of nylon 66 polymer was studied in different percentages. It was observed that, by increasing the percentages of MWNTs contents Tensile strength, Flexural strength, Izod impact strength, Hardness, Heat deflection temperature, Vicat softening point values of the nano composites increased. Melting point and Moisture content of the nano composites were also determined. These values were compared with pure nylon 66, And it was observed that the nano composites exhibited higher values than pure nylon 66.

KEYWORDS: MWNT, NYLON 66, CNT, SWNT

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1. INTRODUCTION

This project work is the study of mechanical and thermal properties of nylon 66/MWNTS nano composites^[1]. Mainly nanotechnology deals with small structures or small sized materials. The typical dimensions spans from subnano meter to several hundred nano meters^{[2][3]}. A nano meter is one billionth of a meter, or 10^{-9} m.

A commercially available nylon66 / MWNTs nano composite master batch (85+15%) was diluted with PA66 to get 0.5, 1, 1.5, 2 wt % of nano composites^[3]. Melt compounding is the best method for mixing of nylon 66 and MWNTs which is carried in injection molding machine.

Nylon 66 (poly hexamethylene diamine adipamide) is a polyamide made from adipic acid and hexamethylene diamine. It has a dense structure and melting point is 265°C . It has unique properties rather than other polymers. On the other hand, Nylon 66 is a thermoplastic, which can be repeatedly melted and molded again and again by simple heating

The unique mechanical and thermal properties of MWNTs make very attraction for fabricating of new advanced materials of nylon 66^{[5] [15]}. The combination of nylon 66 and MWNTs showing improvement in mechanical and thermal properties, Compared to other polymer with MWNTs^[16]. The outstanding combination is done with the help of injection molding to achieve successful commercial developments in mixing^{[17] [18]}.

Figure 1: Multi Walled Carbon Nanotube.

2. EXPERIMENT

2.1. Materials

Nylon 66 / MW NTS nano composite master batch PLASTICYL PA1501 was purchased from Nanocyl S.A.RUE DE L'Esor 4 (real density 1165 G / L, MFI 300°C, 20kg, 4mm- 0.8). Nylon 66 (1.14g / cm³ at 25°C, melting point =263.35) purchased from sigma Aldrich was used to prepare nano composite.

2.2. Sample Preparation

Procedure

Nylon 66 has a highly hygroscopic nature ^[23]. So it has to be predried at 80°C for 3hrs in a hot air oven ^{[1][19][20]}. Nylon 66 / MWNTs nano composite is prepared by dilution of nylon 66 / MWNTs Master batch with nylon 66. For 0.5% of nylon 66 / MWNTs nano composite, add 2900 gms of nylon 66 and 100 gms of master batch. These two are fed in a injection molding machine with high speed.

Table 1

0.5 %	dilution	-	2900gms	nylon	66+100gms	nylon	66 / MWNTs	nano composite
1 %	dilution	-	2800gms	nylon	66+200gms	nylon	66 / MWNTs	nano composite
1.5 %	dilution	-	2700gms	nylon	66+300gms	nylon	66 / MWNTs	nano composite
2 %	dilution	-	2600gms	nylon	66+400gms	nylon	66 / MWNTs	nano composite

2.3. Injection Molding

Injection molding is a manufacturing process for producing different parts from both thermoplastic and thermosetting plastic or other materials including elastomers, metals, glasses ^{[15][16]}. Here 2900 gms of nylon66 and 100 gms nylon66/MWNTs master batch were fed through a hopper into a heated barrel with a reciprocating screw ^{[19][20]}. The samples are made for both pure nylon 66 and nylon 66 / MWNTs nano composites. The injection speed is at 70 cm³ / s and the material melts at 270 °C ^{[20][21]}. The screw delivers the raw material forward, mixes and homogenizes the thermal and viscous distributions of the polymer. The heating barrel is 200-240-270-300°C. When enough material has gathered, the material is forced at high pressure about 70 bar. The mould is at 80°C. For each test 10 samples are made by using different moulds. Holding pressure is 35 bar. The products were dried in an oven for 40 hrs at 25°C prior to testing of properties ^{[24] [25]}. For nylon 66 the temperature barrel changes. i.e. 180-220-235-265°C

Table 2 shows wt % of MWNTs in nylon 66. The flexural strength results are in Table 2. There is a straight increase with increase in MWNTs percentages. The bending strength of nylon 66 MWNTs nano composites were very higher than compared to pure nylon 66 as shown in Figure 2. The reason is there is a very good attraction between the atoms of nylon

66 and MWNTs. So the bonds are nearer and regularly arranged [61]. Hence flexural strength is increased.

Table 2: Tensile Strength of Nylon 66 and Nylon 66 / Mwnts Nano Composite Flexural Strength of Nylon 66 and Nylon 66 / Mwnts

Pure nylon 66 (N / Mm ²)	Dilution to 0.5 % (N / Mm ²)	Dilution to 1.0 % (N / Mm ²)	Dilution to 1.5 % (N / Mm ²)	Dilution to 2.0 % (N / Mm ²)
81.75	105.312	120.848	135.396	171.38

Table 3

Pure Nylon (Mpa)	Dilution to 0.5 % (Mpa)	Dilution to 1.0 % (Mpa)	Dilution To 1.5 % (Mpa)	Dilution to 2.0 % (Mpa)
117.712	231.592	251.826	270.59	293.092

Figure 2

2.4. Tensile Strength

Wt % of MWNTs in nylon 66 Vs Izod impact strength Impact strength values of nylon 66 and nylon 66 / MWNTs nano composite were shown Table 4. The impact strength of nano composites was increased as shown in Figure 3. The impact strength of the material depends on the molecular orientations and flexibility of the material [62]. Due to addition of MWNTs orientation of molecules increases. So at sudden shocks also it requires more energy to break the sample. Impact strength of nylon 66 / MWNTs nano composite increases with increase in of MWNTs loadings.

Table 6 shows the addition of MWNTs contents with nylon 66 increases the hardness value because it may decrease the mobility of the polymer molecule and segment chain [63]. The molecules are regularly arranged in nylon 66/ MWNTs nano composite. The fig 4.4 shows the increasing values of hardness with increasing percentage of MWNTs.

Table 4

Pure Nylon 66	Dilution to 0.5 %	Dilution to 1.0 %	Dilution To 1.5 %	Dilution to 2.0 %
64.54	91.4966	135.166	148.9566	155.04

Figure 3

Table 5: Hardness of Nylon 66 and Nylon

Material	Revolutions Per 15 Sec		Hardness
	Major Load	Minor Load	
Nylon 66	2	1	75M
0.5 % nano composite		1	90M
1 % nano composite	3	3	100+10=110M
1.5 % nano composite	3	3	100+25=125M
2 % nano composite	3	3	100+40=140M

Table 6: 66 / MWNTs Nano Composite Comparision

Pure nylon 66	Dilution to 0.5 %	Dilution to 1.0%	Dilution to 1.5 %	Dilution to 2.0 %
75M	90M	110M	125M	140M

wt% of MWNTs in Nylon 66 Vs Hardness

Figure 4

2.5. Heat deflection temperature

Figure 5: Heat Deflection.

2.6. Temperature of Nylon 66 and Nylon 66 / MWNTs Nano Composite Comparision

With addition of MWNTs to nylon 66 increases the heat deflection temperature. due to decreasing the segmental mobility of the polymer molecule and increasing the crystallinity ^[64]. So as a result the composite is more thermo stable and increased continuous service temperature.

The vicat softening points of these nano composites are increased while increasing the percentages of MWNTs. The values are summarized in the Table 7. Mainly VSP depends on amount of test load and rate of heating ^[65]. For engineering materials 5 Kg load is applied and therate of heat increasing is carried uniformly throughout the process. And thus it resulted an increase in this VSP. The Figure 6 shows the increased values. % Moisture content

The strength of the nylon 66 / MWNTs nano composite is increased while increasing the MWNTs content. The crystallinity of the nano composite is increased because the molecules are regularly arranged ^[66]. The tensile strength and flexural strength are related to moisture content. The Figure 7 shows the decreasing line Melting point

Melting point depends on the intermolecular force of attraction between molecules and segmental mobility of molecules. With increasing the MWNTs content the molecular mobility will be restricted ^[67]. This may due to increase the crystallinity of the polymer. As a result the melting point of the composite increases with increasing the MWNTs content which is clearly observed in following Figure 8.

Table 7: Vicat Softening Point

Pure nylon 66 (⁰ C)	Dilution to 0.5 % (⁰ C)	Dilution to 1.0 % (⁰ C)	Dilution to 1.5 % (⁰ C)	Dilution to 2.0 % (⁰ C)
240	286.16	311.966	339.5	350.16

Figure 6: Vicat Softening Point of Nylon 66 and Nylon 66 / Mwnts Nano Composite Comparision.

Figure 7: Moisture Content of Nylon 66 and Nylon 66 / Mwnts Nano Composite.

Table 8

Nylon 66 (°C)	0 % 5 Nano Composite (°C)	1 % Nano Composite (°C)	1 % 5 Nano Composite (°C)	2 % Nano Composite (°C)
265	279	283	294	300

Figure 8: Melting Point of Nylon 66 and Nylon 66/Mwnts Nano Composite.

3. CONCLUSIONS

It was observed that the mechanical properties such as tensile strength, flexural strength, Izod impact strength and hardness of nylon 66/MWNTs nano composites increased with increase of MWNTs contents for each composition. Thermal properties such as HDT, VSP, and melting point increased with the increase of MWNTs contents for each nano composites. Moisture content decreased by increasing

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