Enhancing the Mechanical properties of polypropylene(PP) and High density polyethylene(HDPE) by blending with Multi walled Carbon Nano tubes(MWCNT)

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Abstract - **This study proposes melt-blending polypropylene (PPCP) a high-density polyethylene (HDPE) and Multiwalled Carbon Nanotubes that have a similar melt flow index (MFI) to form PP/HDPE/ MWCNTs polyblends. The influence of the content of HDPE and MWCNTs on the properties and compatibility of polyblends is examined by using a tensile test, flexural test, Izod impact test, scanning electron microscopy (SEM), and X-ray diffraction (XRD). The SEM results show that PP, HDPE and MWCNTs are incompatible polymers with PP being a continuous phase HDPE and MWCNTs being a dispersed phase. XRD results show that PP, HDPE and MWCNTs are not compatible, and the combination of HDPE and MWCNTs is not correlated with the crystalline structure and stability of PP. However, according to mechanical property test results, the combination of HDPE and MWCNTs improves the impact strength of PP.**

keywords - **Polypropylene co-polymer (PPCP), High-density polyethylene (HDPE), Multiwalled Carbon Nanotubes, Scanning electron microscopy (SEM), X-ray diffraction (XRD), Izod impact test**

I. Introduction

"Polymer is a Compound of high molecular weight formed by repetitive combination of small molecules called monomers. This process is called Polymerisation. Polyblends are a invention formed by melt-blending or solvent-blending by using two or more polymers.

The mechanical or physical properties of polyblends be subject on to the phase morphology, action between constant and isolated phase and the component ratios. In terms of processing technique, phase morphology trusts on the processing technique, including extrusion, injection moulding and manufacturing conditions, such as temperature and shear force. For real applications, polyblends are typically finished by physical blending of melt processing, which mixtures several polymers on an extruder, compounder and mixer.

Melt processing doesn't need solvents to achieve polyblends with high distribution; the vital factors being particular temperature control and operation period. However, attention to the thermal degradation produced by high shear force and high temperature is essential PP is one of the most usually used polymers, and has virtuous mechanical properties, heat resistance, less cost, ease of dispensation and complete recyclability. Its major disadvantage is small impact strength, which can be enhanced by a toughening . Therefore, a blending method, the most efficient and easy, has been widely used. For a toughening alteration, other thermoplastics or elastomers are utilise as converters to mix with PP in order to increase its toughness .This study leads to enhancing the mechanical properties of polypropylene and HDPE by blending with MWCNT's. The present works have been done by mixing either PP and HDPE or PP and MWCNT's, but we concentrate on mixing of 3 materials to enhance the overall properties. Mixing methods used currently are melt mixing, twin screw or single screw extruder we can either use any of the above and proceed by injection moulding method.

2. Specimen preparation

We have prepared 1 kg of material and the composition is as follows:

MWCNT(COOH functionalised)	2.5 gms
PP(3530 grade)	698.25 gms
HDPE(180M50 grade)	299.25 gms

2.1 SINGLE SCREW EXTRUDER

It is a machine used to form a plastic product into the essential shape. The machine heats the plastic raw material to its melting point, after which it is pushed through a die that gives the material its shape and it is considered as a very basic form of extruder that simply melts and forms the material. Together, they are responsible for conveying the solids,melting and pumping the melt through the die the heated barrel melts the polymer and transports the material through the die

Fig 1 : Single Screw Extruder

Fig 2 : Long Wires

Fig 3 : Pallets

First we mix all the required materials manually in a plastic cover and we feed the material into single screw extruder. We get the material as a output in the form of long wires then it is palatised.

2.2 INJECTION MOULDING MACHINE

Parts are produced by injecting the material into the mould, used for making thin walled plastic parts buckets, tooth brush, medical devices, syringes valves, bottle caps, automative parts, storage containers, toys, combs, dust pan, dash board etc. In this process grains of plastics is fed by a ram from a hopper forcefuly into heated barrel. As the grains are gradually moved forward by a screw type plunger, the plastic is moved into heated chamber forcefully. Where it is melted as the plunger proceed the melted plastic through a nozzle forcefully into the mould cavity through the gating system. The mould remains cold so that the plastic hardens as soon as the mould is completed.

Fig 4 : Injection Moulding Machine

Fig 5 : Specimens

We feed the material in the form of pallets into the pneumatic injection moulding machine to get the final specimens and we tested the mechanical properties of these specimens.

3. TESTING METHODS

We conducted Impact, Tensile and Flexural test for the Specimens.

3.1 IMPACT TESTING

IMPACT stands for Immediate Post-Concussion Assessment and Cognitive Test
These machines estimate an object's capacity to survive high-rate loading and it is normally used to regulate the service life of a material. Impact resistance can be among the most interesting qualities to measure. The capacity estimate this property is particularly useful in assessing product liability and safety.
There are two types of tests: Charpy Impact test and IZOD Impact test . Charpy tests are commonly achieved on metals, but a limited polymer and plastics can also be tested. IZOD tests can be achieved also on metal or plastic specimens.

Fig 6 : Impact Testing Machine

Fig 7 : Specimens

Speed Calculations

R=ZL2/6D

R= (0.1×52.62)/(6×3.5)

= 13.17 mm/min

R= Rate of cross-head motion(speed) mm/min

L=support span 1mm

d=Thickness mm

Z= Rate of straining of outer fiber mm

3.2 TENSILE TESTING

Tensile strength is a measurement of the force required to pull something such as wire, rope, or a structural beam to the point where it breaks. The tensile strength of a material is the extreme amount of tensile stress that it can take before failure.The tensile strength of a metal is essentially its capacity to withstand tensile loads without failure, on the other hand ductility measures a material's ability to deform under tensile stresses. This is an significant factor in metal forming processes since brittle metals are more possible to rupture.

Fig 8 : Tensile Testing Machine

Fig 9 : Specimens

3.3 FLEXURAL TESTING

The flexural strength of a material is defined as the extreme bending stress that can be applied to that material before it yields and it is also known as modulus of rupture, bending strength or transverse rupture strength. The normal purpose of a flexure test is to measure flexural strength and flexural modulus. Flexural modulus is considered from the slope of the stress v/s. strain deflection curve.

Fig 10 : Universal Testing Machine

Fig 11 : Specimens

4. TESTING RESULTS

4.1 IMPACT TESTING RESULTS FOR COMBINATION OF PP AND HDPE

PP+HDPE		
WIDTH(mm)	**THICKNESS(mm)**	**IMPACT STRENGTH(J)**
13.02	3.5	3.9
13.02	3.5	3.4
13.02	3.5	3.6
AVERAGE IMPACT STRENGTH		**3.63**

Table 1 : Impact Strength of PP & HDPE

4.2 IMPACT TESTING RESULTS FOR COMBINATION OF PP, HDPE & MWCNT

PP+HDPE+MWCNT		
WIDTH(mm)	**THICKNESS(mm)**	**IMPACT STRENGTH(J)**
13.02	3.5	4.2
13.02	3.5	5.7
13.02	3.5	5.3
AVERAGE IMPACT STRENGTH		**5.0**

Table 2 : Impact Strength of PP, HDPE & MWCNT

Average Impact strength is **3.63 J** by mixing of PP & HDPE and average Impact strength of PP,HDPE and MWCNT increases to **5 J**. From the above tables we can observe that the tensile strength is more when all the three materials are mixed.

4.3 TENSILE TESTING RESULTS

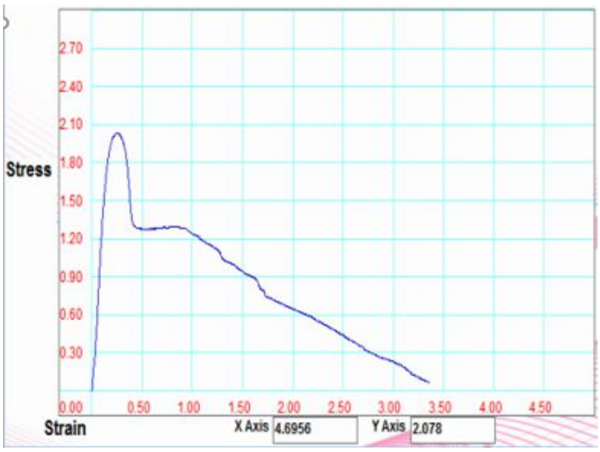


Fig 12 : Stress-Strain curve of PP & HDPE

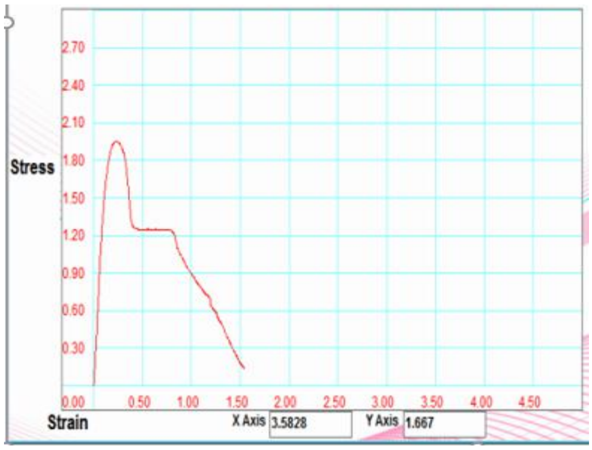


Fig 13 : Stress-Strain curve of PP, HDPE & MWCNT

Average tensile strength is **19.956 (N/S)** by mixing of PP & HDPE and average tensile strength of PP,HDPE and MWCNT decreases to **19.138(N/S)** . From the above curves we can observe that the tensile strength is less when all the three materials are mixed.
Report interprets the stress v/s strain curve and tensile strength at peak load is less in the combination of PP,HDPE and MWCNT when compared to the combination of PP and HDPE.

4.4 FLEXURAL TESTING RESULTS

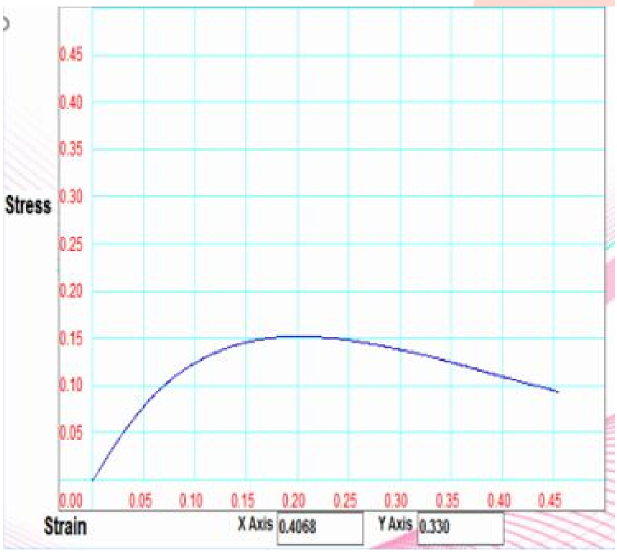


Fig 14 : Stress-Strain curve of PP & HDPE

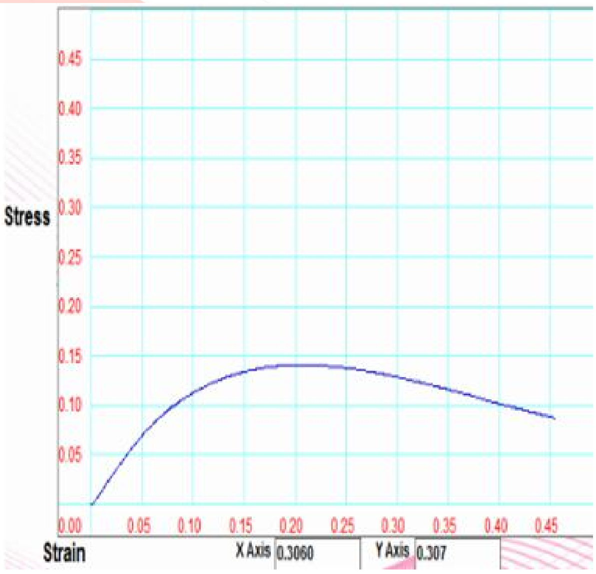


Fig 15 : Stress-Strain curve of PP, HDPE & MWCNT

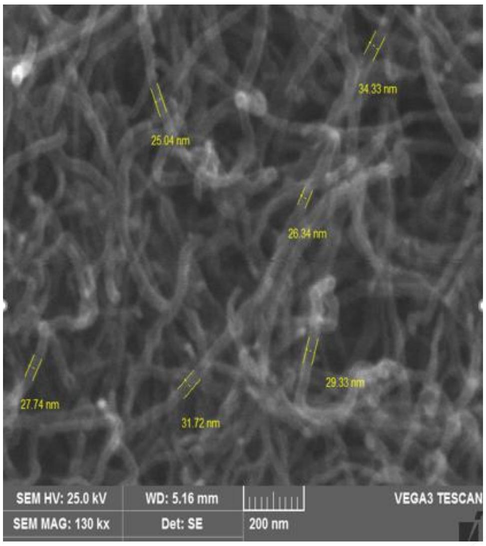
Average flexural strength is **33.175 (N/S)** by mixing of PP & HDPE and average flexural strength of PP,HDPE and MWCNT increases to **33.702 (N/S)** . From the above curves we can observe that the flexural strength is more when all the three materials are mixed.
Report interprets the stress v/s strain curve and flexural strength at peak load is more in the combination of PP,HDPE and MWCNT when compared to the combination of PP and HDPE.

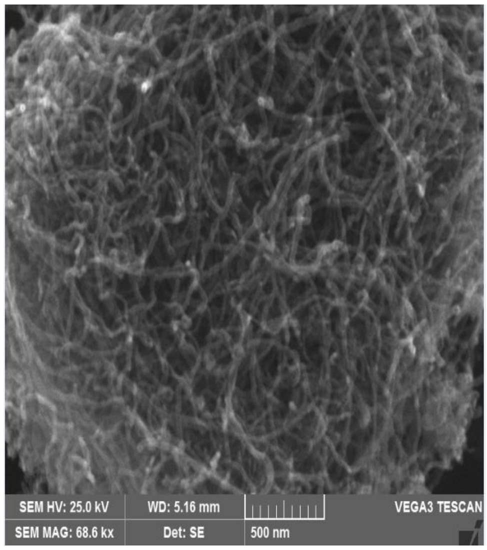
5. SCANNING ELECTRON MICROSCOPE

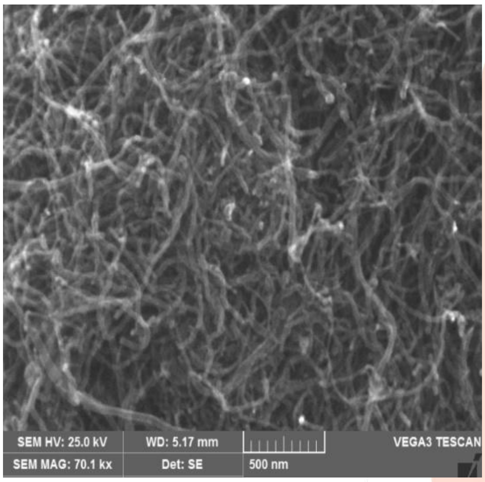
The Scanning Electron Microscope (SEM) is used for observation of surface of the specimens. When the specimen is irradiated with a fine electron beam (called an electron probe), secondary electrons are emitted from the specimen surface. Topography of the surface can be detected by 2-D scanning of the electron probe over the surface and acquisition of an image from the detected secondary electrons.

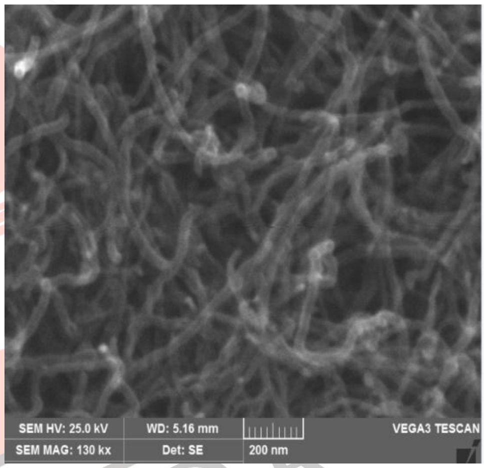
SEM uses a focused electron probe to abstract structural and chemical information point-by-point from a region of interest in the sample. The high spatial resolution of a SEM makes it a powerful tool to characterise a wide range of specimens at the nanometre to micrometre length scales. A SEM is a type of Electron microscope that pictures a sample by scanning it with a high energy beam of electrons in a raster scan pattern.

5.1 SEM IMAGES FOR MWCNT









6. X-RAY DIFFRACTION

The atomic planes of a crystal cause an incident beam of X-rays to affect with one another as they leave the crystal. This phenomenon is called X-ray diffraction.

XRD is used for

- To find the average spacings between layers or rows of atoms.
- Govern the orientation of a single crystal or grain.
- Find the crystal structure of an unidentified material.
- To find the size, shape and internal stress of small crystalline regions.

Fig 16 : XRD Instrument

The geometry of an X-ray diffractometer is such that the model rotates in the path of the collimated X-ray beam at an angle θ while the X-ray detector is mounted on an arm to gather the diffracted X-rays and rotates at an angle of 2θ. The instrument used to sustain the angle and rotate the model is termed a goniometer. For typical powder patterns, data is gathered at 2θ from ~5° to 70°, angles that are preset in the X-ray scan. When electrons have adequate energy to dislodge inner shell electrons of the target material, characteristic X-ray spectra are produced. These spectra consist of numerous components, the most common being Kα and Kβ. Kα consists, in part, of Kα1 and Kα2. Kα1 has a somewhat shorter wavelength and twice the intensity as Kα2..

6.1 XRD REPORT FOR PP, HDPE & MWCNT

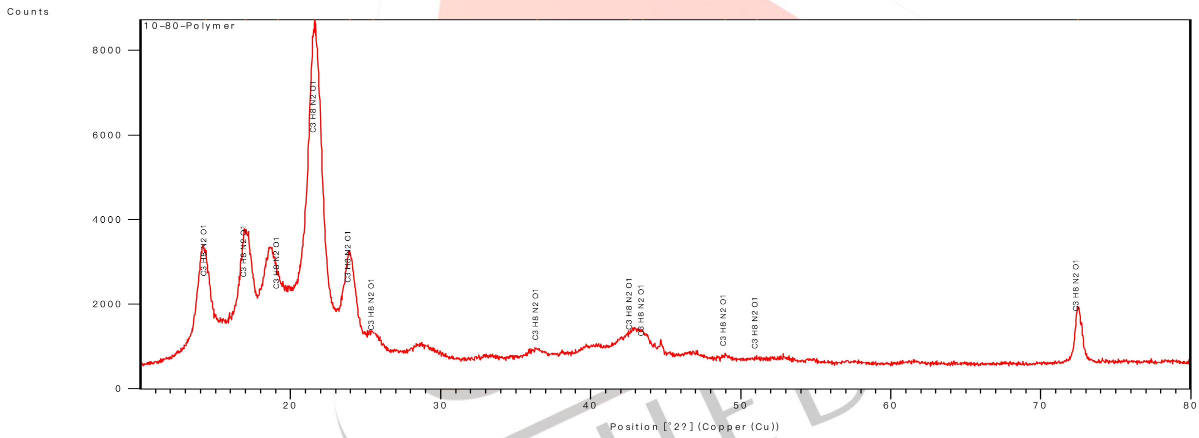


Fig 17 : Graph of Counts per second V/S 2θ

Pos. [°2θ]	Height [cts]	FWHM Left [°2θ]	d-spacing [Å]	Rel. Int. [%]
14.3427	1642.54	1.0992	6.17042	33.24
17.0046	1563.97	1.2468	5.21005	31.65
19.1718	1257.70	2.2960	4.62571	25.46
21.6225	4940.85	1.0979	4.10664	100.00
23.9475	1386.15	0.9855	3.71294	28.05
25.5082	263.75	0.9824	3.48919	5.34
36.4486	103.81	0.7862	2.46308	2.10
42.6783	399.16	1.6590	2.11686	8.08
43.4984	258.31	0.9393	2.07883	5.23
48.9542	63.96	0.6578	1.85915	1.29
51.0669	15.80	25.2487	1.78708	0.32
72.4690	960.89	0.4693	1.30318	19.45

Table 3 : Peak List

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	98-040-0522	33	N,n-dimethylurea	0.000	0.115	C3 H8 N2 O1

Table 4 : Pattern List

6.2 Measurement Conditions

Dataset Name	10-80-Polymer
File name	D:\XRD Data\Vinod-BIT-Bangalore\10-80-Polymer.xrdml
Comment	Configuration=Stage: PW3071/xx Bracket, Owner=User-1, Creation date=11/11/2015 10:37:34 AM Goniometer=PW3050/60 (Theta/Theta); Minimum step size 2Theta:0.001; Minimum step size Omega:0.001 Sample stage=PW3071/xx Bracket Diffractometer system=XPERT-3 Measurement program=C:\PANalytical\Data Collector\Programs\10-80-Normal scan-Nov-11.xrdmp, Identifier={FFAB5CB4-76CA-4DBB-8D9C-31B3D858E6BA} PHD Lower Level = 5.63 (keV), PHD Upper Level = 12.88 (keV)
Measurement Start Date/Time	11/05/2022 2:28:23 PM
Operator	User
Raw Data Origin	XRD measurement (*.XRDML)
Scan Axis	Gonio
Start Position [°2θ]	10.0150
End Position [°2θ]	80.0050
Step Size [°2θ]	0.0300
Scan Step Time [s]	0.8000
Scan Type	Continuous
Offset [°2θ]	0.0000
Divergence Slit Type	Fixed
Divergence Slit Size [°]	0.8709
Specimen Length [mm]	10.00
Receiving Slit Size [mm]	0.3800
Measurement Temperature [°C]	25.00
Anode Material	Cu
K-Alpha1 [Å]	1.54060
K-Alpha2 [Å]	1.54443
K-Beta [Å]	1.39225
K-A2 / K-A1 Ratio	0.50000
Generator Settings	30 mA, 40 kV
Diffractometer Type	0000000011174082
Diffractometer Number	0
Goniometer Radius [mm]	240.00
Dist. Focus-Diverg. Slit [mm]	100.00
Incident Beam Monochromator	No
Spinning	No

7. CONCLUSION

- Average imapact strength of PP and HDPE is 3.63 J where as the combination of PP, HDPE and MWCNT is 5 J. We can conclude that the imapact strength is more when all the three materials are mixed.
- Tensile strength at Peak load of PP and HDPE is 19.956 N/S where as the combination of PP, HDPE and MWCNT is 19.138 N/S. We can conclude that the tensile strength is less when all the three materials are mixed.
- Flexural strength at Peak load of PP and HDPE is 33.175 N/S where as the combination of PP, HDPE and MWCNT is 33.702 N/S. We can conclude that the flexural strength is more when all the three materials are mixed.

TEST	PP and HDPE	PP, HDPE and MWCNT's
IMPACT STRENGTH(J)	3.63	5
TENSILE STRENGTH(N/S)	19.956	19.138

FLEXURAL STRENGTH(N/S)	**33.175**	**33.702**

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