Study of Thermal and Mechanical properties of High Density Polyethylene and Nanoparticle of Silica Composite

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Abstract

Nanoparticles of Silica are used as filler for forming High density polyethylene based composite. Silica nanoparticles have been obtained from many resources and are preferred for reinforcement of High density polyethylene because of their low cost, high aspect ratio and fairly good mechanical properties. The composite has been prepared by using compression moulding and stirrer. The mechanical properties of the composite are analyzed by using tensile and Impact tests. The thermal properties of the composite are characterized using Thermo-Gravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC). The tests performed on the composite indicate that the mechanical and thermal properties of the HDPE composite have been improved when it is reinforced with nanoparticles of silica.

Keywords: Compression moulding; HDPE (High Density Polyethylene); reinforcement; Impact test; TGA; DSC.

1. Introduction

In recent era, the composite materials are getting popular in industries due to their properties such as high stiffness and strength, corrosion and chemical resistance, ease of fabrication, economically efficient and environment friendly behavior. Current researches majorly concentrate on the mechanical and thermal properties of the developed composite materials [1-3]. Most of the composites based on thermoplastic are developed from polypropylene and polyethylene[4].

A composite material may be defined as a combination of two or more constituent materials with significantly different chemical or physical properties that, when combined, produce a material with distinct characteristics from the individual components [5-6].

High Density Polyethylene is the majorly used matrix material for the composite material development due to its properties such as good adhesion, excellent mechanical properties, chemical stability, low cost, high hardness and adhesive strength, high damping properties.

In order to increase the scope of its application, it may be blended with various inorganic fillers. It has been observed that high loadings of macro sized fillers are required to improve the tensile strength while only small amount of nano-sized fillers such as titanium, $CaCo_3$, silica is sufficient to improve the toughness of the composites[7].

This work evaluates reinforcement of high density polyethylene using silica nanoparticles. It is reported that lots of silica is wasted in India. The wasted silica is mixed with high density polyethylene in order to find commercial applications. High density polyethylene is mixed into silica nanoparticles at 3 % by weight in order to form high density polyethylene composite. The composite is compression moulded at specific time and temperature. High density polyethylene and silica nanoparticles reinforced composite has better mechanical and thermal properties than other. Colom et al prepared HDPE composite using a compounding step at 200 Centigrade in crucible and moulding step at 150 Centigrade in a compression Die for up to 50 minutes and 4 hours for cooling in air[8].

Chrissafis et al.[9] have observed that addition of SiO_2 nanoparticles enhances the mechanical and thermal properties of the composite materials. PMCs are light weighted with high stiffness and strength along the direction of the reinforcement. Therefore they are useful in aircraft, automobiles, and other moving structures [10].

2. Experimental procedure

Silica nanoparticles have been selected for reinforcement of HDPE. Silica nanoparticles have special properties for binding. So we have chosen the silica nanoparticles. A composite sample has been prepared by mixing homogeneous liquid of HDPE and nanoparticles of SiO_2.

The following tests are performed on the composite in order to analyze thermal and mechanical properties.

2.1 Mechanical Testing

2.1.1 Tensile Test

The tensile test is generally performed on flat specimens. The most ordinarily utilized example geometries are dog bone shape and the straight side composes with end tabs. The ductile tests were led by ASTM D-3039 standard on an electronic Universal Testing Machine. The range length of the example was 120 mm. the tests were performed with crosshead speed 9.7 mm/min.

Fig. 2.1.1 UTM machine with Sample loaded condition for tensile testing

2.1.2 Impact Test

Impact strength is defined as the ability of material to absorb applied energy. Its unit is J/m. The impact test was conducted according to ASTM D-256A standard on a computerized impact testing machine

Fig. 2.1.2 Impact testing machine with Sample loaded condition

2.2 Thermal Testing

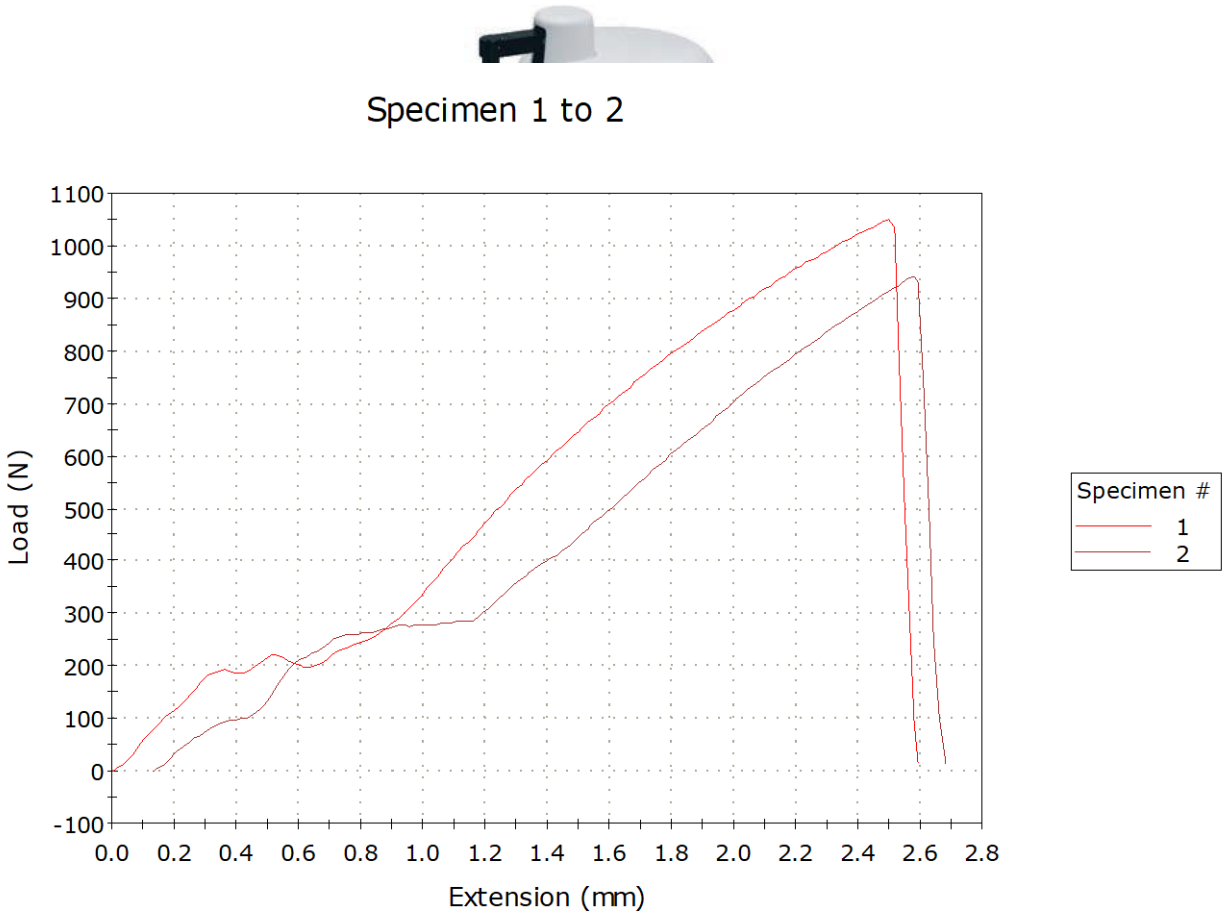
2.2.1 Thermal Conductivity test using LASER Flash

The LFA 447 NanoFlash is based on the well-known flash method. In this method, the front side of a plane-parallel sample is heated by a short light pulse. The resulting temperature rise on the rear surface is measured using an infrared detector. By analysis of the resulting temperature versus-time curve, the thermal diffusivity can be determined. LFA 447 offers a variety of flash systems to cover a broad range of applications and temperatures from -125°C upto 2800°C. LFA 447 is designed as a cost-effective, easy-to-operate, highly accurate instrument for testing between room temperature and 300°C. The tests were conducted according to ASTM E 1461.

Fig. 2.2.1 LFA 447 used for thermal conductivity, thermal diffusivity and bulk density

2.2.2 Differential Scanning Calorimetry (DSG) and Thermo-Gravimetric Analysis (TGA)

STA 6000 offers simultaneous measurement and analysis of weight change and heat flow of sample materials of pharmaceutical tablets or polymers. By combining flexible differential temperature analysis (DTA or DSC) with proven thermo gravimetry (TG) technology, the STA 6000 enables to generate accurate and reliable results while simplifying data interpretation. The tests were conducted according to ASTM E 1269.



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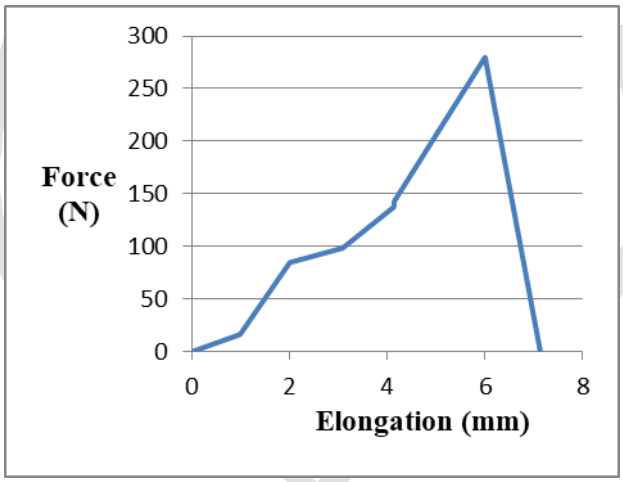

Fig. 3.1.1 Force V/s Elongation curve with 0% Silica nanoparticles

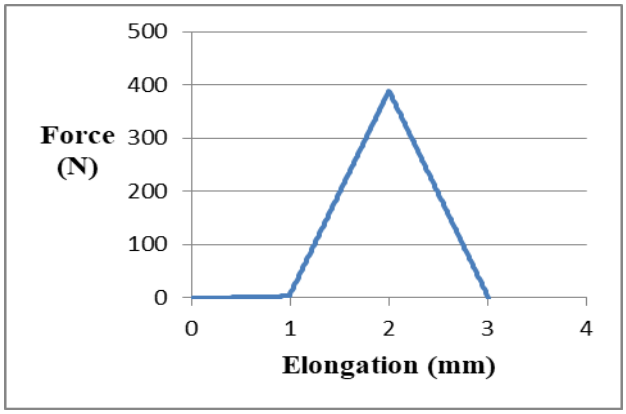

Fig. 3.1.2 Force V/s Elongation curve with 5% Silica nanoparticles

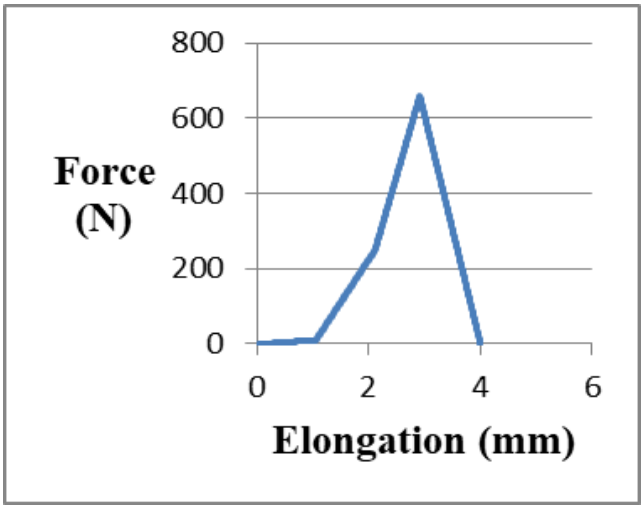

Fig. 3.1.3 Force V/s Elongation curve with 10% Silica nanoparticles

Table-3.1: The obtained Tensile Strength of different composite samples

SPECIMEN	TENSILE STRENGTH (MPa)		
	SAMPLE A	SAMPLE B	SAMPLE C
1	2.913	4.077	6.416
2	3.737	4.625	8.781
3	3.397	5.331	7.972
AVERAGE	3.349	4.677	7.723

SAMPLE A: HDPE composite with 0% Silica nanoparticles

SAMPLE B: HDPE composite with 5% Silica nanoparticles

SAMPLE C: HDPE composite with 10% Silica nanoparticles

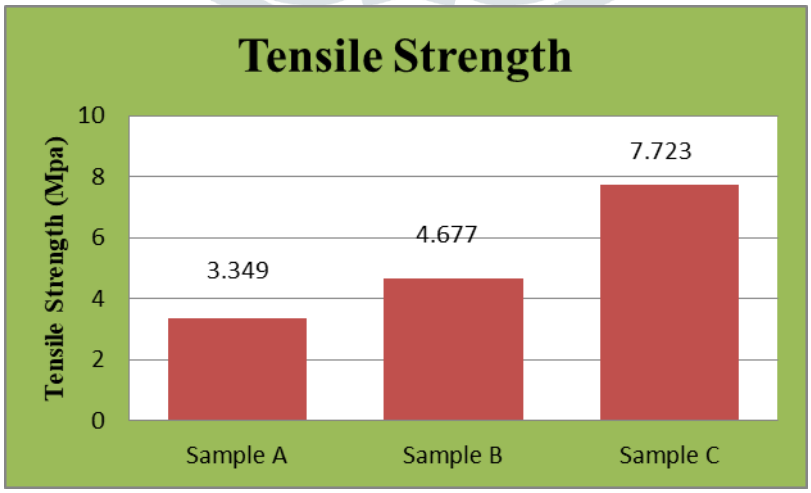

Fig. 3.1.4 Comparison of Tensile Strength with the variation of the Silica nanoparticles

From the above results the tensile strength is increased by 39.35% and 130.6% with the addition of 5% and 10% addition of silicon carbide respectively due to the high strength of silicon carbide.

3.2 Impact Test:

On the basis of test conducted on respective samples, the results of impact test are as follows:

Table-3.2: The calculated impact strength of different composite samples

SPECIMEN	IMPACT STRENGTH (J/m)		
	SAMPLE A (0% Silica nanoparticles)	SAMPLE B (5% Silica nanoparticles)	SAMPLE C (10% Silica nanoparticles)
1	171	211.7132	251.9235
2	171	214.7136	237.4328
3	169.5689	205.8392	259.6667
AVERAGE	170.5229	210.7553	249.6743

The average value of above results are tabulated in the graph.

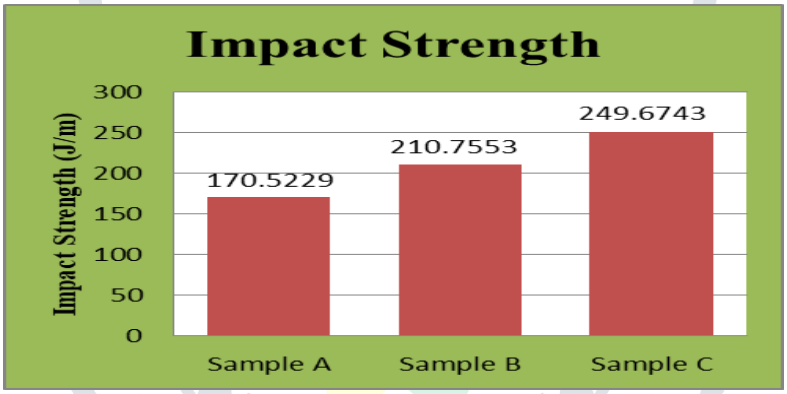

Fig. 3.2.1 Comparison of Impact Strength with the variation of the Silica nanoparticles

From the above results the Impact strength is increased by 23.58% and 46.42% with the addition of 5% and 10% addition of silicon carbide respectively due to the high strength of silicon carbide.

3.3 Thermal Conductivity test using LASER Flash

The thermal conductivity of composites Sample A, B, C are tabulated in the graph.

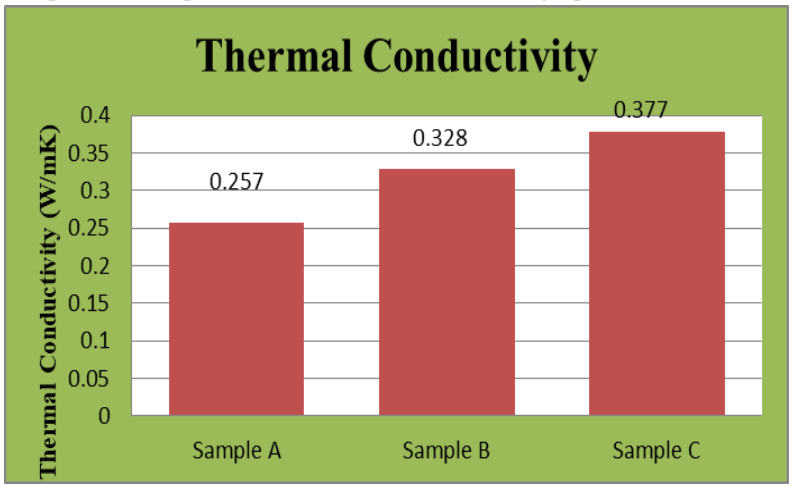

Fig. 3.3.1 Comparison of Thermal Conductivity with the variation of the Silica nanoparticles

3.4 DSC and TGA test using STA

DSC and TGA test is carried out in simultaneous thermal analyzer in the temperature range of 30^0C-100^0C with the heating rate of 1^0C/min. For maintaining the variation of temperature above the atmospheric condition liquid nitrogen is used with the rate of 20ml/ min.

The heat flow for sample A, B and C are shown in the following figures

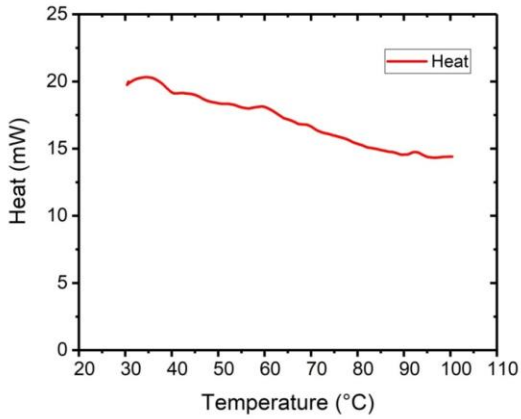

Fig. 3.4.1 Heat flow V/s temperature for Sample A

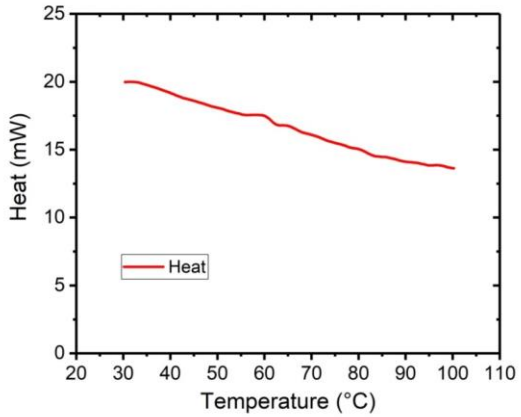

Fig. 3.4.2 Heat flow V/s temperature for Sample B

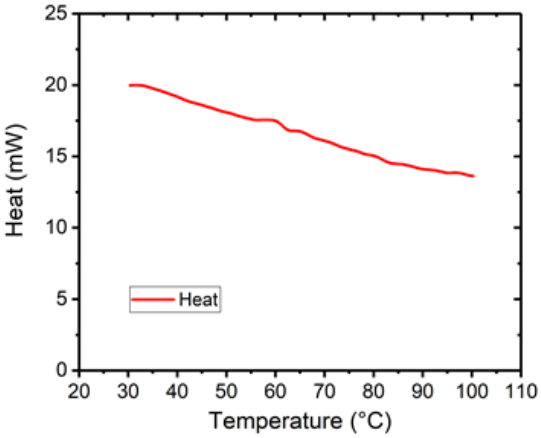

Fig. 3.4.3 Heat flow V/s temperature for Sample C

4. Conclusions

The HDPE and nanoparticles of Silica composite was synthesized for the composition of three different samples containing HDPE 10% by weight by varying Silica nanoparticles in Matrix as follows (Sample A) 0% by wt. Silica nanoparticles , (Sample B) 5% by wt. Silica nanoparticles, and (Sample C) 10% by wt. Silica nanoparticles. Three specimens of each sample were tested for obtaining the mechanical properties and one specimen for each sample for thermal properties according to ASTM standard. DSC and TGA tests were conducted for the heat flow and thermal stability in STA6000 apparatus. The conclusions are as follows:

- From tensile testing results it is observed and concluded that tensile strength is increased by 39.35% and 130.6% with the addition of 5% and 10% addition of Silica nanoparticles respectively.
- From Impact testing (IZOD method) it is observed and concluded that the Impact strength is increased by 23.58% and 46.42% with the addition of 5% and 10% addition of Silica nanoparticles respectively.
- From the results the thermal conductivity is increased by 27.63% and 46.69% with the addition of 5% and 10% addition of Silica nanoparticles respectively.
- From STA we observed that thermal stability increases with increasing Silica nanoparticles.

5. References

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