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Reinforcing Effect of Montmorillonite Nanoclay on Mechanical Properties of High Density Polyethylene Nano composites

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Abstract. In recent years, many researches focused on the polymer materials to study the characteristics and to enhance the mechanical properties of the nano composites in order to understand the factors which lead to the desired dispersion of nano clay in the polymer matrix. The samples used in this work were prepared through melt compounding, using high-density polyethylene and organo-modified clay of montmorillonite (MMT). During manufacturing of MMT/HDPE nano composites, a silane modifier and polyethylene grafted with maleic anhydride (compatibilizer) were added to get good surface finish and to act as bonding agent respectively. In addition, the compatibilizer will help in attaining better intercalation. Using a Plastograph-Mixer through twin-screw extruder, the high density polyethylene and different weight percentages (0, 1, 2, 3, 4 wt. %) of MMT are mixed and subsequently the composite is produced in the form of solid material. ASTM standard specimens for various tests are produced using injection molding machine with respective dies. The prepared experimental specimens for various tests like tensile, flexural, impact and shore-hardness are tested for its respective strengths. From this investigation, it is concluded that the addition of MMT nanoclay in HDPE has significantly influenced the mechanical properties of the composites.

1. Introduction

Nano particles reinforced with high density polyethylene attracted more attentions due to improvement of mechanical properties. Normally higher surface area of nano particles facilitates higher interface and strong interaction between matrix and filler materials. The dispersion state of nano particles in polymer matrix is of great importance for the mechanical properties of the composite. A homogeneous dispersion of the nano particles can contribute better to the property improvement. However, a homogeneous dispersion in a polymeric matrix is a difficult task due to the strong agglomerating tendency of the nano particles. Therefore, to disperse homogeneously nano particles into polymer matrix is a challenge for enlarging the application of nano composites.

Sung-Po Liu et al concluded in the tensile test, the MMT weight percentage 3 wt. % has the best result, increased by 0.26%. In the shore hardness test, the MMT 3 wt. %, strengthened by 0.62%. In the wearing test, the MMT 3 wt. %, strengthened by 2.6%. [1]. Minkova et al determined that the nano composites have been compatibilized by ethylene–acrylic acid copolymer (EAA), acrylic acid grafted HDPE (HDAA) and maleic anhydride grafted HDPE (HDMA). The clay was montmorillonite Cloisite 15A. The results have shown that the thermal stability, the reduction of the flammability and the micro hardness of HDPE/clay nano composites, compatibilized by HDAA and HDMA are higher than those for nano composite compatibilized by EAA [2]. Min et al. prepared HDPE-g-MAH and HDPE/MMT nano composites by melt blending using twin-screw extruder with two-step process. The influence of MMT on the crystallinity, thermal properties and mechanical properties as a function of compatibilizer was investigated by Differential Scanning Calorimetry

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(DSC), thermo gravimetric analysis (TGA) and universal testing machine, respectively [3]. Nalini et al found that the optimized clay composition of 5% was tested by varying the wt% of compatibilizer (5, 10, 15, and 20) to obtain better performance properties of nano composites. [4]. Palani kumar et al concluded that the effect of montmorillonite (MMT) on the morphology, and mechanical properties of polypropylene (PP). The strength and modulus of the nano composites increases with addition of 5 wt% of nanoclay and impact strength and hardness of the nano composites increases with addition of 3 wt% of nanoclay [5]. Water absorption decreased with nanoclay loading and barrier properties was lowered with the increasing nanoclay content conclude the addition of nanoclay improves its water absorption and thickness swelling property [6].

This paper presents the comparative study on the mechanical properties of the effect of nanoclay (MMT) on tensile, impact, hardness and flexural strength of HDPE-clay nano composites.

2. Preparation and Testing of HDPE/MMT Nano Composites

HDPE and clay were dried at 70 °C inside the vacuum oven for 1 hr. Various weight % of MMT (1, 2, 3 and 4 %) were taken separately for processing the HDPE/MMT nano composites. A mixture of HDPE pellets and nanoclay were poured into the twin screw extruder by passing through compartments maintained at temperatures of 105°C, 120°C, 135°C, 140°C, 150°C, 170°C and 185°C. The mixture of HDPE and MMT obtained from the twin screw extruder has been in wire form. This wire form mixture was cut in to pellets using pellets cutter. The pellets were fed into injection molding machine with a spindle speed of 150 rpm to get specimens as per the ASTM standard for various tests. The specimens prepared as shown in Fig.1 for tensile tests were as per the ASTM standard (D638). Tests were carried out in 20 KN tensometer. Among mechanical properties, tensile strength is one of the most frequently used parameter for design of any structures. According to the ASTM D638 standard, dumb bell-shaped specimens were prepared by using specific die in the injection moulding machine. Five specimens from each categories were tested and the average of all in each composition was considered to represent its tensile strength.

The impact test was used to exert impact strength of the specimen and to break the material by the impact of the external force. It can determine the energy absorbed by the broken specimen, and shows the impact strength of material per unit area of cross section. The specimens were prepared according to the ASTM D256, and the experiments were conducted using a shore hardness testing machine. Shore hardness testing machine was used to find the hardness number of the samples. The shore hardness test was invented by Albert F Shore in 1906. The shore hardness testing Machine type D calibrated scale was used. In addition, it is a quick operation and can reach to 1000 or more times per hour. This experiment will adopt the type D shore hardness testing machine. The experiment was conducted according to the ASTM D790 standard. In flexural test, the specimens were prepared for flexural tests as per the ASTM standard (D790). Tests were carried out in 20 KN tensometer. The nano composite materials (HDPE/MMT) of different volume fraction (0-4%) were subjected to cyclic load. Then the specimens were tested for its flexural strength and the results were obtained using a tensometer by three point bending test. The maximum load of a specimen was taken from the load–deflection curve and the flexural strength was calculated.

3. Result and Discussion

The prepared nano composites of different weight % (0 to 4%) of nano clay with HDPE were tested for their tensile, impact, shore hardness and flexural strength. Significant enhancement in tensile strength, flexural strength, impact strengths and shore hardness number have been observed, when increasing the nano clay content in the polymer matrix. The values are tabulated in table 1 and separately indicated from Fig.2 to 5. Table1 shows the relations of composition of HDPE/MMT nano composites prepared by melt blending method, with mechanical properties.

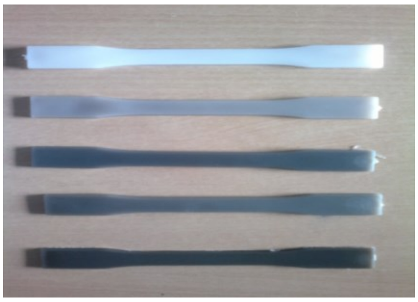

Fig.1. HDPE/MMT (0-4%) Nano composite specimens prepared for tensile test.

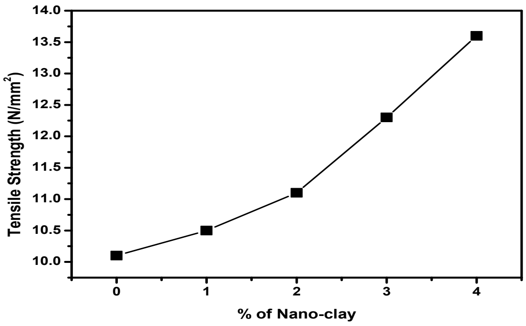

Fig. 2. Tensile Strength of various % of Nano Clay with HDPE

TABLE 1 Tensile Impact and Hardness Number of HDPE/MMT Nano composite

S.No	Composition	Tensile Strength (N/mm^2)	Impact Strength ($Joule/m^2$)	Shore Hardness Hs
1	0%MMT +HDPE	10.1	10.7	61.3
2	1% MMT + HDPE	10.5	10.7	61.3
3	2% MMT + HDPE	11.1	13.3	61.8
4	3% MMT + HDPE	12.3	18.7	64.6
5	4% MMT + HDPE	13.6	13.3	63.9

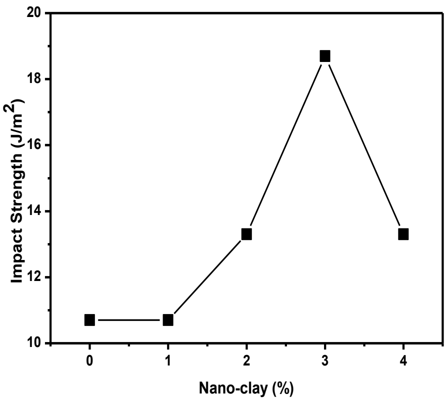

Fig. 3. Impact Strength of various % of Nano Clay with HDPE

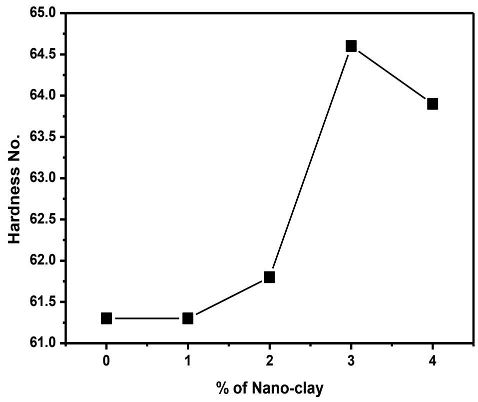

Fig. 4. Shore Hardness number of various % of Nano Clay with HDPE

From table 1, it was observed that the tensile strength increases with increase in % weight of nanoclay with high density polyethylene. It was also observed from figure 2 that, the MMT 4 weight percentage with HDPE has the more strength than other specimens. It can be understood that by increasing the weight percentage of nano-clay in HDPE, the required amount of tensile strength can be obtained. It was observed from Fig 3, that the maximum impact strength is absorbed in 3 wt % and decreases at 4wt % nanoclay with HDPE. But the impact strength is constant at 0% and 1 wt % nanoclay and there is an increase of impact strength for 2 wt% nanoclay. Hence, an optimum amount of nanoclay can be added to get high impact strength for specific applications. From Fig 4, it was observed that the hardness number increases from 1 wt % to 3 wt % of nanoclay with HDPE and beyond which decrease of hardness number occurs. From Fig 5, it is seen that nanoclay added up to 3 wt % increased the flexural strength. A rise in flexural strength and hardness number up to 3 wt % indicate composite nature of material, that may due to composite can exhibit higher impact strength despite of higher hardness. However larger addition of compatibilizer and nanoclay need degradation. Pooling of the compatibilizer with higher addition of nanoclay resulted in poor performance.

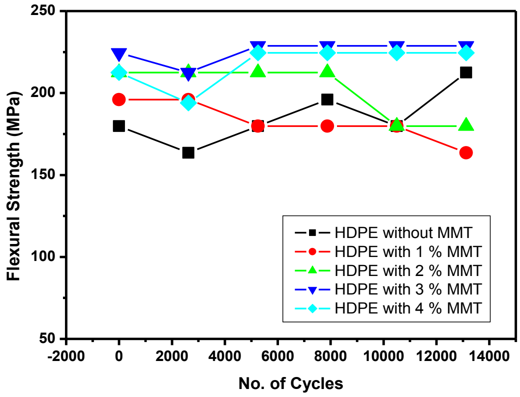

Fig. 5. Flexural strength of various % of Nano Clay with HDPE

4. Conclusion

The HDPE polymer filled with nanoclay (MMT) at various concentrations (0 wt %, 1 wt. %, 2 wt. %, 3 wt. %, and 4 wt. %) was prepared by using injection molding method. Tensile, impact, hardness and flexural tests were conducted and the corresponding observations are:

- The tensile strength increases with increase in wt% of MMT nanoclay
- The impact strength of nanoclay having 3 wt % of MMT has higher strength compared to other specimens.
- The shore hardness value of nanoclay having 3 wt % of MMT has higher value than other specimens.
- The flexural strength of nanoclay having 3 wt % and 4 wt % were observed than the others, even with increase in no of cyclic loading.
- In all type of specimens, during the introduction of cyclic loading the flexural strength slightly increases and maintains approximately constant there off.

From this investigation, it is concluded that the appropriate addition of MMT nanoclay in HDPE has significantly influenced the mechanical properties of the composites.

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