Thermal and Impact properties of HDPE/Sayong Clay

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Abstract

This study shows the effect of clay apply on the thermal and impact strength properties of high-density polyethylene (HDPE). For this purpose, 1wt%, 3wt% and 5wt% of clay reinforced with HDPE composites that being prepared through a melt mixing by using a compounder system. HDPE then undergo Izod Impact strength test in temperature range of 25°C. The result showed that the accumulated clay particles that arise in addition of 3wt% of clay caused the decreased in impact strength. To study the melting point and crystallization behaviour of clay reinforced with HDPE, DSC were conducted on the samples at the temperature of 50°C to 180 °C and at the rate of 10°C/min. The result showed that the more the clay added to hdpe, the higher the melting point of the mixture. The crystallization behaviour of HDPE affected with addition of Sayong clay in which make the composite easily become crystal form even at high temperature

Keywords: HDPE, Izod Impact, Sayong clay, thermal analysis(DSC)

1. Introduction

High density polyethylene (HDPE) is one of the polyethylene thermoplastic that produce from the cracking process of petroleum. Application of HDPE are widely used mostly in industrial application because it is known as an engineering thermo-plastic (Shin et al, 2013). The unique feature of high-density polyethylene (HDPE) and the abundant of the raw materials also makes it one of the best plastic types to use in our daily life. This is due to its lightweight, has great mechanical properties, almost zero dampness retention, great boundary for mugginess and protection from scraping and corrosion. It is very crystalline structure in contrast with different sorts of polyethylene (Grigoriadou et al., 2013). However, there are some issues involved in the use of HDPE that is the ability to cope with high heat and high impact because HDPE is known to have low thermal resistance (Dikobe & Luyt, 2017a). High capacity to withstand heat makes this polymer an important ingredient for use today. The composition of the HDPE need to improve in order get the good structure that can bear the high temperature and impact compared to the pure structure of HDPE.

In order to improve the structure of HDPE, the addition of nanoparticle such as montmorillonite in this polymer can escalate the properties of polymer (Chrissafis et al, 2009). Clay is obtain from the soil layer which has high surface area that contains trace of metal oxide and other minerals. Clay is chosen as one of the material that has good properties which can withstand high temperature. It also offering ascend to a high level of polymer--clay surface relation which brings about boundary and mechanical properties that are superior to those of the base material (Gopakumar et al. 2002). Clay minerals that are raw are the most commonly used in the inorganic material. Clay also considered low-cost material and eco-friendly which is abundant in all over the world. Counterbalanced clay such as Na-Mt contains mostly polar structure makes the clay suitable with the most polymer (Asgari et al, 2017). The incorporation of the polymer and clay is theoretically able to shows the good result in impact and has the ability to increase the resistant of the polymer towards the high temperature (Barbosa et al., 2014).

The surface modification act as a main key role in improvement of HDPE/clay composite structure (Zhang et al.2006). The modification of platinum plate inside and outside is required to obtain polymer clay which seems to have high-density polymer and high-density clay applications. A trace of clay nanoparticles can provide a greater contrast to heat resistance and force attraction in the molecule structure because of the larger surface area of clay. It also because of the minerals contain in the clay such as silicate are rich intercalation and ion-exchange that make the polymer matrix become compatible. The compatible structure provide a minimal increasing in the strength of the HDPE. The amount of the clay added and the size of clay strongly reinforcement the polymer matrix (Xidas &

Triantafyllidis, 2010).The addition of clay will also not affect if the HDPE crystallization rate does not reach the appropriate amount (Dikobe & Luyt, 2017).

Studies conducted by University College London have found that the durability of clay to high heat depends on the type of mineral contained in it (Clays and Clay Minerals, 1999). Nanoparticles clay are well known adhesive that can modify the properties of the HDPE (Minkova et al., 2009). But in this experiment, Sayong clay is used as the adhesive compared to the nanoparticles. This experiment is to see either the capability of Sayong clay to increase the properties of HDPE is similar to the nanoparticles clay or not. This experiment is similar to the others. In most studies where clay was used, it was used in small amounts and as a compatibilizer. This experiment interest was to explore the possibility of using Sayong clay as a significant part of the filler in polymer matrix and comparing the properties of these compound and composites with those of composites with the different composition of clay which is 1wt%, 3wt%, and 5wt% added to 99%, 97% and 95% of HDPE respectively. Sayong clay powder was chosen as natural fibre filler because of its easy processing and environmental friendliness. To our knowledge, there are only a few reports on similar systems (Gao et al, 2008).

Theoretically, the addition of clay may influence the properties change of HDPE especially toward thermal behaviour but for the high impact is still under discussion. The current study focused on a comparison of the properties of HDPE and clay mixed, and on the composites formed when mixer were mixed with various amounts of fibre (sayong clay) at the extruder or compounding machines to get the HDPE/Sayong mixtures. Then palletized the compound at the palletized to get pallet for injection moulding. Of special interest in this study was the impact of mechanical structure and thermal influences at the samples. For the thermal, the sample is test by using Differential Scanning Calorimetric (DSC) and for the impact test, the Izod impact tests were carried out using Toyo Seiki Digital impact tester. The objectives of this study is to investigate either addition of Sayong clay in HDPE can improve the rate of this polymer when expose to high temperature and the mechanical properties toward high impact.

2. Methodology

2.1 Materials Chemicals

Three kilogram (3kg) of clay was obtained from Labu Sayong, Kuala Kangsar, Perak. A total of about five kilogram (5kg) of high density polyethylene (HDPE) used in this study (homopolymer) was obtained from Lotte Chemical Titan Sdn. Bhd in Pasir Gudang. Melted plasticizer was used as a compatibilizer.

2.2 Preparation of Clay

More than two kilogram (2kg) of Sayong clay was prepared in a steel tray and had been shape into small pieces in order to increase the surface area of the clay. The tray full of clay then was put in the oven at range of 135°C – 140°C for 20 minutes. The clay then had been crushed into small particle and had been sieved into 125 micron in size. The Sayong clay was stored in a seal plastic bag and kept away to avoid humidity surroundings.

2.2.1 Formulation of Composites

Dried Sayong clay and pellets high density polyethylene (HDPE) were mixed based on their weight ratios (Table 1). Once the ingredients of each composite formulation were weighed to a 0.01g precision, they were manually mixed. Care was taken to mix the ingredients as homogenously as possible. The compounding of the three compositions was performed with mixing conditions of 100 rpm and 180°C for 15 min in the single-screw extruder to produce HDPE/Sayong clay composite in pellet form.

Table 1: Blend Formulation of HDPE/Sayong clay

Compositions	Composition of HDPE %	Mass of HDPE based on 1.5 k of cla	Composition of cla wt%	Mass of Clay based on 1.5 k
A	99	1485		15
B	97	1455	3	45
C	95	1425	5	75

2.2.2 Injection Moulding

HDPE and Sayong clay composite in the form of small pellets are fed into the injection unit and then heated to a molten stage (transforming from a solid state to a liquid). They were melted using heater bands and the frictional action of a reciprocating screw barrel. The plastic is then injected through a nozzle into a mould cavity where it cools and hardens to the configuration of the cavity.

2.3 Testing

2.3.1Izod Impact Test

The Izod impact tests were carried out using Toyo Seiki Digital impact tester with an impact velocity of 1 m/s. The v-notched specimens were subjected to the impact test in the temperature range of 25°C in accordance with ASTM D-256.

2.3.2 Differential Scanning Calorimetry (DSC)

The crystallization and melting characteristics of clay/HDPE were determined by using differential scanning calorimetry (DSC) in accordance with ASTM E-793. The Perkin Elmer DSC 6000 was utilized, running composites samples through a heat-cool-heat cycle at temperature 50°C to 180°C and held about 1 minute at high temperature to erase the thermomechanical history and to achieve a relaxed melt. Then the samples was cooled to 50°C at the rate of 10°C/min, and a second scan was reheat at 50°C to 180°C at the rate of 10°C/min.

3. Results and discussion

3.1Impact test

Table 2 and Figure 1 show the impact strength of HDPE for all composites. Pure HDPE displayed impact strength of 12.183kJ/m^2. This value decrease significantly with addition of 1wt% and 3wt% of clay but then increase with the addition of 5wt% clay. In general, presence of solid filler usually degrades strength and toughness of polymeric materials (Valek, 2011). The accumulated clay particles that arise for the composition in 3wt% clay was believed to be the cause for the decrease in impact strength. Increasing clay content causes increase in clay accumulation and decrease in interparticle distance, which lead to lower the aspect ratio of clay particle and lower the contact surface area, resulting in weak bond between HDPE matrix and clay, in which subsequently lower their impact strength (Bashar, 2014).

Table 2: Impact Strength value for all compositions

Compositions	Compositions of Clay (wt %)	Impact strength (kJ/m^2)
A	0	12.183
B	1	3.952
C	3	3.587
D	5	4.085

Above all, the impact strength of D is higher than of B and C. The result means that 5wt% clay has better dispersion in HDPE matrix. This improvement may attribute to the increase in toughness of the composite (George, 2013). Quality dispersion of particles in matrix also plays important role for an improvement of properties (e.g. impact properties) of clay (Agubra, 2003). The positive of the clay as a filler depends on the amount of clay added to the HDPE matrix (Valek, 2011). In general, composition display great improvement in mechanical properties, such as the strength, compared to pure HDPE upon addition of minimal amount of microsize clay particles (Tanasa, 2014). High content of clay in the HDPE matrix tend to limit its use as filler (Agubra, 2003). Suitable amount of reinforcing clay particles presented in the HDPE matrix act as efficient impact absorption agents in the polymer (Kusmono, 2013).

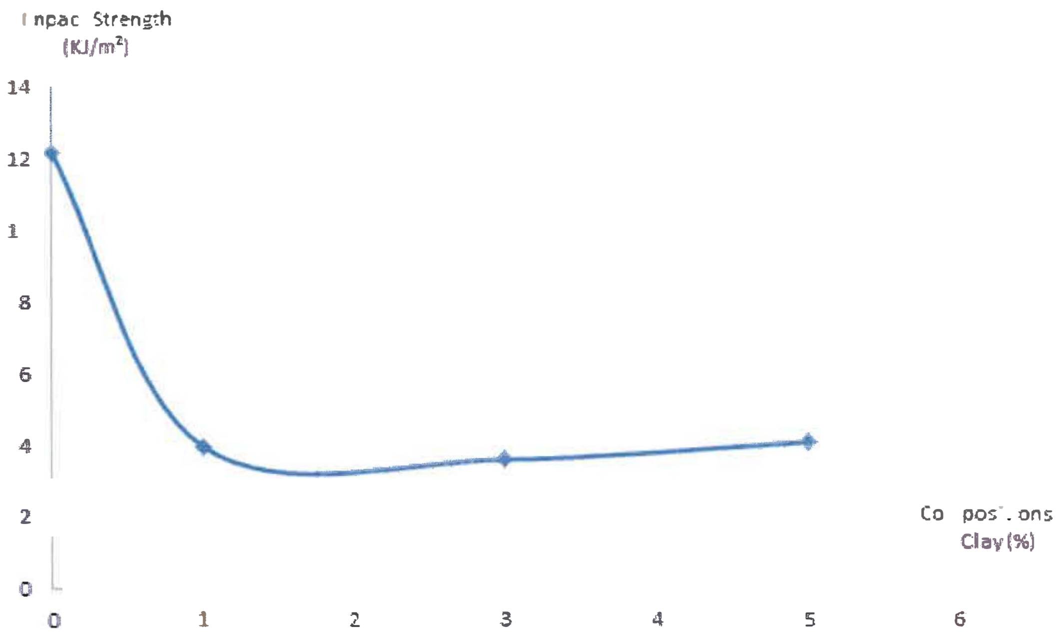

Figure 1: Graph of the impact strength against the composition of clay

3.2 Differential Scanning Calorimetry

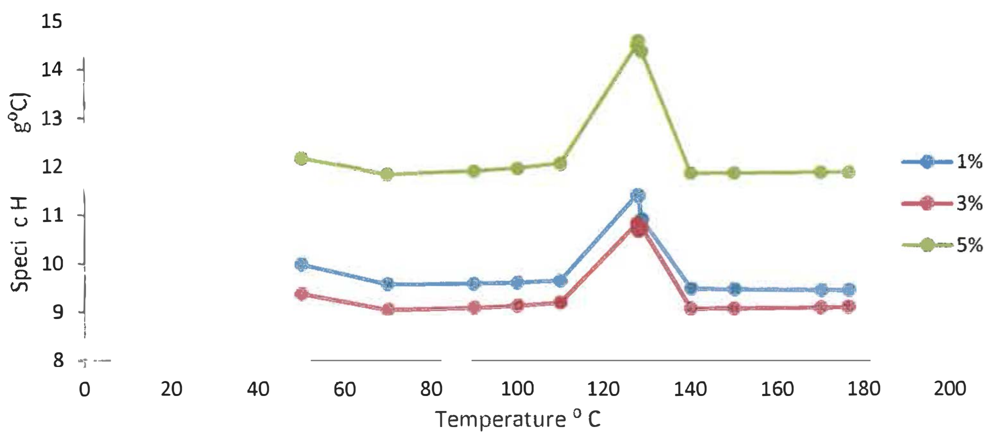

Figure 2: Graph of specific heat and temperature with different composition of HDPE/Sayong clay (1wt%, 3wt% and 5wt %)

DSC test was performed to determine melting point and crystallize temperature of HDPE/Sayong clay mixture. Figure 2 illustrates the melting graph that had been plotted based on 3 different percentages of HDPE/Sayong clay with the specific heat. The green line is refer for 5wt% of clay that mixed to HDPE, second line at the middle is refer to 1wt% of clay mixture and at the red line is refer to 3wt% of HDPE/Sayong clay mixture. All HDPE/Sayong clay mixture start to melt at around 110°C then the mixture absorb heat until it fully melt at its melting point.

The melting point is increasing due to increase of composition of clay used. HDPE has a slightly low melting point compared to HDPE/Sayong clay. The more the composition of the clay the more required energy to increase But there are also some disadvantages towards this clay, with added of clay theoretically it will lower the strength of the compositions.

Figure 3 show the crystallization temperature graph. Thermal properties for the three samples were investigated using DSC diagram that obtains from the DSC machines. From the graph, it shows the different crystallization rates between pure HDPE and different percent of HDPE/Sayong clay.The crystallization parameters T_o-onset temperature is the temperature where the sample start to undergo crystallization process, T_e -the end peak of crystallization process and the T_p -peak temperature is the temperature that the composite start to form crystal. The data for the figure 3 is summarized in Table 4.

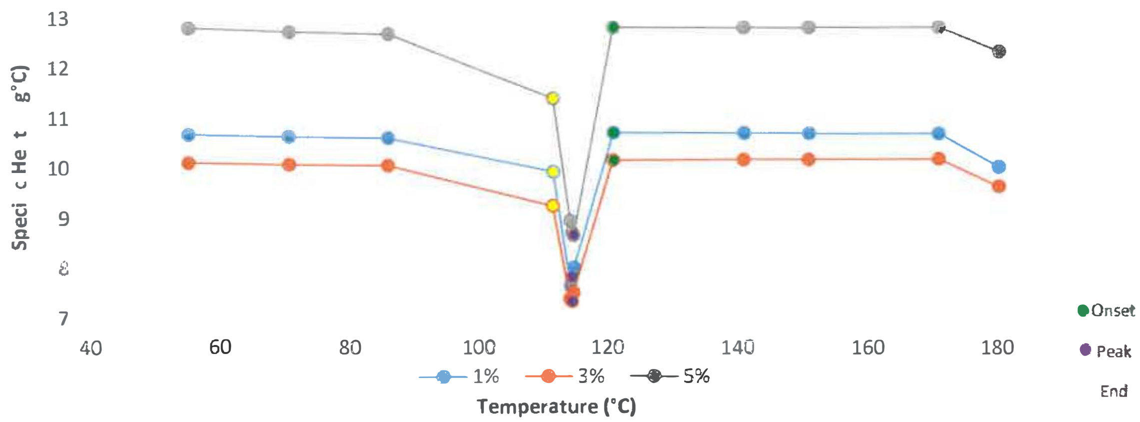

Figure 3: Graph of crystallization temperature for 1wt%, 3wt% and 5wt% of HDPE/Sayong clay

From Figure 3, the addition of clay in HDPE shows the increasing of the parameter T_o and T_p. It is also shows that the addition of 1wt% of clay does not give a significant change in the crystallization temperature between the pure HDPE but, the addition of 5wt% clay in HDPE, there is observable change in the value of T_p. The value of T_p at 5wt% is 114.63°C and 1wt% is 114.1°C so the difference is close to 1°C.

Table 3: Parameter for crystallization rate

Cooling rate (°C/min)	Crystallization parameter (°C)	1% Clay	3% Cla	5% Clay
10	To	115.9	116.18	116.46
	Tp	114.1	114.43	114.63
	Te	111.58	110.76	110.3

For the crystallization of the pure HDPE and Clay/HDPE, crystallization started at almost same temperature, but the three samples with difference amount of clay reach the peak temperature for the crystallization early before the pure HDPE. It means that at high temperature, the Clay/HDPE composite can become crystallize form compare to the pure HDPE that need to reach lower temperature to become crystallize after undergo heating process. These results are almost same with the prediction that the addition of clay as filler in HDPE make the composite easily becomes crystal form even at high temperature. Other than that, the clay filler in HDPE cause the size of crystal grew thicker than the HDPE composite. The higher temperature affect the size of crystal to become thicker (Chen & Yan, 2013). Table 4 shows summarized of melting temperature, crystallization temperature and crystallinity level.