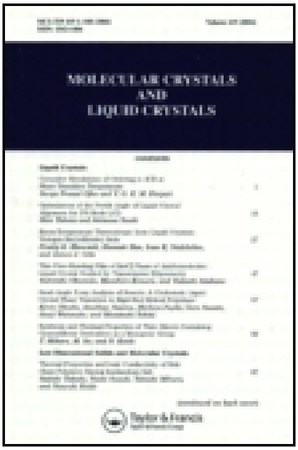

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Clay as a Filler in the Thermoplastic Compounding

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INTRODUCTION

The addition of fillers and additive in plastic is well recognized to impart desired properties to the virgin plastic such as improvement of mechanical and thermal properties as well as of cost(1). There are, however, some adverse effects upon using such fillers, for example, toughness and ultimate elongation of polymers often suffer with the addition of fillers. A practical interest originated from the addition of clay minerals as polymers fillers to enlarge their potential and actual applications. Almost any powdered material can be used as a filler, the common ones being obtained from natural deposits. Of the several hundred fillers used, those which find spread use are the various grades of $CaCO_3$, quartz and silica flours, talc and various clay.(2) Kaolinite has been used as a filler for thermoplastics. Kaolinite is characterized by small grain size and plate shape. These properties are useful in the production of a compound with high strength and electrical insulation. The advantages of using clay as filler in plastics are in the producing a smooth surface finishing, low water absorption and improving the mechanical properties while increasing the chemical and weathering resistances(3).

Egypt is very reach in clay minerals mines. The application of these clays as fillers in thermoplastic and rubbers is limited compared to calcium carbonate. Therefore the aim of this work is to study the efficiency of using Egyptian Kaolinite as a filler to improve the physical properties of the recycled polyethylene (RPE).This process is of major importance to the Egyptian plastic industry due to the absence of its local production, where 400.000 MT are the average year by estimated imported quantities. Which necessitates a big PE recycling in Egypt with a need to improve its quality.

Table 1. Chemical analysis of Egyptian kaolinite

Oxide	SiO_2	Al_2O_3	TiO_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Others
%	45.18	36.8	1.98	1.32	0.34	0.10	0.10	0.06	0.32

II. EXPERIMENTAL WORK

II. 1. Materials and Compound

Recycled polyethylene, was used as matrix. Egyptian kaolinite was used without any treatment of a particle size less than 63 μm. Polyethylene was initially mixed with fixed amount of clay ranging between 5 and 40 wt% , and extruded by a twin-scrow APV 2030 extruder. During mixing no powder fogs were shown such in the case of other fillers which provides good environmental working conditions. The extrusion showed much easier and smoother process, that means, higher lubrication effect was obtained compared to the other traditional fillers.

The chemical analysis of the clay was determined by using x-ray fluorescence as shown in table 1. The density of the clay and recycled polyethylene was determined .The loss in ignition(a measure of the quantity of organic matter present) of the clay was determined by heating 5 gm of clay in a muffle furnace at 450°C for 24h, which was then cooled in a desecrator and weighed. The difference in weight was taken as the loss upon ignition and was found of 12.5%. The moisture content of the clay was also determined by heating 5 gm of the clay in an electric oven at 120°C for 24h which was then cooled in a desecrator and weighed. The difference in weight represents the moisture content and was found of 4% The desired particle size of kaolinite was separated by using a suitable sieve (200 mesh number 200). Clay having a size above than 63-μm was discarded.

Mechanical Properties

Particles, less than 63 microns of non - treated kaolinite clay were used as a filler without any special treatment. The mixing process was carried out in a turbo-mixer of 3000 rpm and $1m^3$ capacity in the normal traditional industrial way used by a major PE compounded in Alexandria. All different ratios of filler to PE were weighted, mixed and extruded in a similar way and under the same conditions. The palletizing of the compounds was following the water cooling of the compounded extruded PE filaments into 2 mm long pellets of 1 mm diameters. Each compound was calendered into sheets at 180°C and samples were cut by a hollow die punch according to ASTM standard. Those were subject to all mechanical (tensile and hardness) and physical (thermal analysis and thermal conductivity), characterization tests.

The tensile strength was measured by using universal testing machine, Monsanto Tensometer T 2000 It was carried out as per Iso-527. The specimen used was dumbbell-shaped, with a total length 100 μm width breadth of 20 mm. Hardness of kaolinite-polyethylene systems were determined by shore hardness tester type D, serial no. 17399, capacity 140, hardness Shimadzu Seisakusho LD. Japan..

Thermal Analysis

Differential thermal analysis (DTA) for kaolinite-polyethylene systems were recorded with a thermal analyzer Shimadzu with heating rate 20°C/min .

Water Absorption

The examined samples were weighed and immersed in water for two weeks, wiped very well to remove water from the surface of the sample and reweigh. The difference in weight represents the water absorption. The hardness of the samples were also measured again after water absorption in order to study the water absorption effect on the surface hardness of each compound

Thermal conductivity

The thermal conductivity of RPE and FRPE was measured by using DATA analysis software, program 2021, version 3.0 by Anter Corporation 1995.

RESULTS AND DISCUSSION

The addition of clay as a filler to recycled polymer showed very promising interesting results. For instant the processing technique gives a relatively high lubrication effect while extrusion energy was saved as the glass transition point was reduced and consequently the working environment was better compared to the other traditional fillers due to the low fogging of clay powder during mixing of compound.

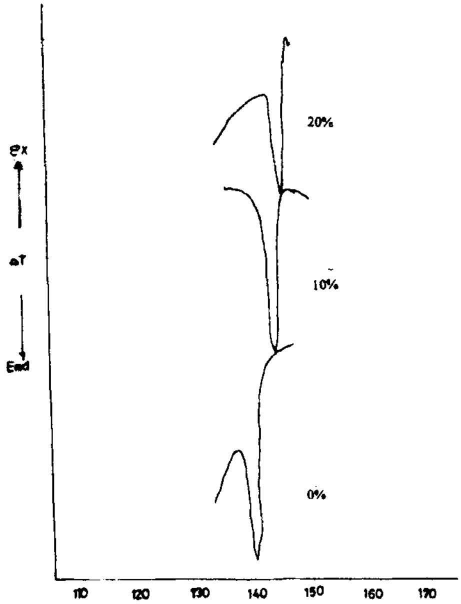

Fig. 1. Differential thermal analysis of RPE at different ratio of clay : 0%, 10% and 20%.

Thermal Analysis

Figure 1 shows the Differential Thermal Analysis (DTA) thermogram of recycled polyethylene filled with kaolinite. The DTA curve of non filled recycled polyethylene shows that the melting temperature is 140°C as indicated from the endothermic peak. This is in agreement with several investigators(4-5). With increase of clay content to polyethylene, the melting temperature shifts to the higher value, from 140°C for non filled polyethylene to 150°C for filled with 20% kaolinite. This result means that the thermal stability is not influenced by the presence of kaolinite, while a slight increase in melting temperature has been noticed at high clay ratio in polymer matrix.. Generally the slight increases in melting temperature may be due to the interaction between OH groups of octahedral layer of clay surface(6)and the hydrogen atom of the RPE through weak intermolecular forces (hydrogen bond) .This force leads to modifications in the crystalline fraction of the matrix or due to the filler surface interaction with polymer through catalytic activity and orientation of molecular segments(7). It has been reported(8) that the high kaolinite ratio does not result in a further increases of the crystallization ratio of a polypropylene and that a limiting concentrating of crystallization nuclei is reached . Our results are in a good agreement with this observation and indicate alimating kaolinite concentration of weight fraction.20 % which the increase of Tm in the composite almost stop.

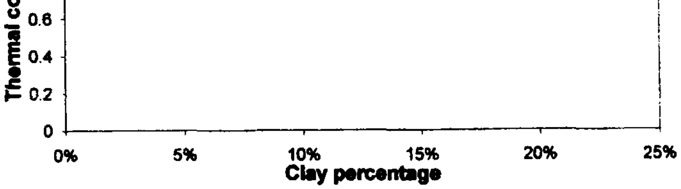

Fig. 2. Thermal conductivity of FRPE at different kaolinite ratios

Mechanical properties

The tensile strength of (RPE) and (FRPE) wear are shown in Fig. 3. The tensile strength of RPE was about 20.5 Mpa. The increase of kaolinite did not affect the strength of REP like PE. There is not much difference in strength of REP up to the until the polymer filled with 30% kaolinite. At the same time theelongation of the FRPE did not decrease considerably as expected (cf. Fig. 4). This high content filler may not be sufficient to decrease the ductility, while it was drastically affected at 40% and 50% koolinite, as the strength decreased sharply. This may be due to the difference in particle size, The chosen clay particles 63 micron being much larger than those of $CaCO_3$, the distribution of clay particle in the polymer matrix may have such major effect and our results were agree with many investigator.(9-10)

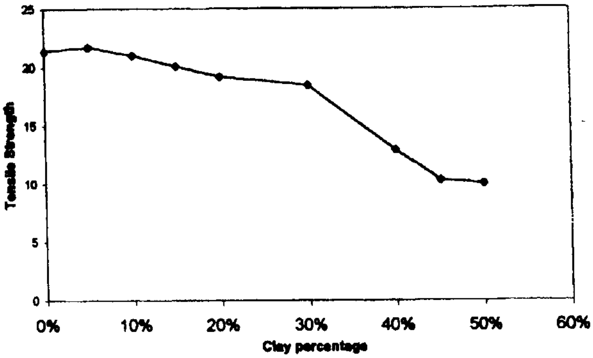

Fig. 3. Tensile strength of the composite FRPE at different clay ratios

The elongation of the composites (FRPE) decreased significantly compared with that of the original polymer and it continued to decrease with the increase of the filler content in FRPE as shown in Fig. 4 showing that the brittleness of the composite increases with kaolinite content (or , in other word, the toughness is decreased with increasing content). The reason must be due to the poor adhesion or bonding of the interface between the polymer matrix (organic) and the kaolinite (inorganic particles) due to the incompatibility between the two phases. The properties of the composites with fillers in the form of flakes were already discussed in literature [11,12]. The shape of kaolinite particles is flake. This flake shape is expected to produce unusually large increase in the strength, especially, as in our case, if the flakes are oriented predominantly in the plane of the film. However, even though in heavy flake composite could have very high strength. Such strengths are difficult to achieve in practice. This is ruled out by our results. It is probable that the flakes are not perfectly aligned or there may not be an optimum overlap of one flake over another. Poorly aligned or stacked flakes act as stress concentrator and reduce the strength of the composite. Table 2. FRPE before and after soaking in water for two weeks.

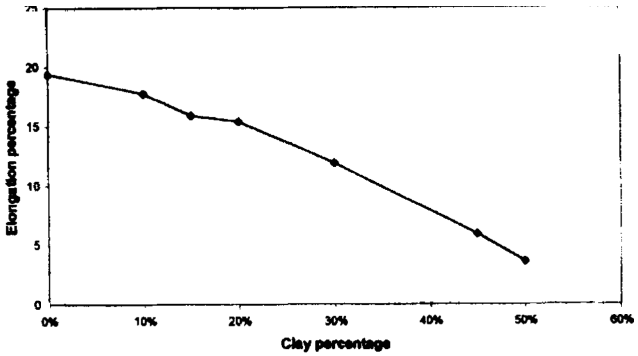

Fig. 4. Elongation percentages of the composite FRPE at different clay ratios

	Hardness	
Filler content %	Before soaking in water	After soaking in water
0	56	54
5	57	50.7
10	58	52
15	58.5	52
30	57	53.7
35	56	50.3
40	55.1	55.7
50	55	53.7

Generally filler cause a dramatic decrease in elongation to break and often decrease the tensile strength of polymer (cf. Fig. 3). The decrease in elongation to break is because polymer filled with rigid particles, all the elongations occur in the polymer phase and the actual elongation experienced by polymer is much larger than that of a measured

Table 3. The differences in weight of FRPE composite before and after soaking in water for two weeks.

Filler content %	Before soaking in water	After soaking in water
0	11.08	11.04
5	5.7	5.69
10	6.13	6.14
15	7.35	7.36
20	4.83	4.83
30	8.19	8.23
35	7.30	7.32
40	6.6.1	6.60
50	5.99	5.97

specimen. Wu et al., (9) reported that the surface treatment of silver powder with coupling agent marginally improved the mechanical properties of polypropylene. The tensile strength of polypropylene was improved to a maximum with talc which was surface modified with a series of modifiers(13). Also, since $CaCO_3$. Also, since $CaCO_3$ was already surface modified with a suitable (stearic acid) coupling agent, there may be improved bonding between the polymer and the filler and hence a higher strength. So, if the kaolinite particles are treated with some silane or chrome coupling agents (which react with the polymeric as well as with the inorganic phase and hence, improve the bonding between the two, then there may be some improvement in the mechanical properties of polypropylene.

Table 2 shows the hardness to the hardness of the PE and FRPE before and after soaking in water for two weeks. With increasing clay content in polymer matrix one observes a slight increase in the hardness of RPE filled with 15% kaolinite before soaking in water. After 15% the hardness slightly decreases. Because for the same weight load, the volumetric fraction of kaolinite will be always smaller if the particle size is large (because of smaller total surface area) and bigger if the particle size is small (because of larger total surface area). Kaolinite particles having a largest particle size less than 63 μm have a smaller volumetric fraction compared to $CaCO_3$ of 4 μm particle size[15]. Hence, with the same polymer quantity, kaolinite will be more suitable for the use as a filler than $CaCO_3$ from a physical point of view, which is considered as another advantage to its use in such applications.

Also, it was observed that the hardness of the RPE and FREP composite was slightly influenced after soaking in water for two weeks. This may be due to the fact that RFPE composite has excellent water resistance and there is no differences in weight of samples before and after soaking as shown in Table 3. This means that during soaking, the RFPE does not absorb water which is considered as another advantage for its use in many applications.

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