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MECHANICAL PROPERTIES OF DRILLING MUD WASTE- FILLED LOW DENSITY POLYETHYLENE COMPOSITES

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ABSTRACT

Polymer composites filled with low weight fractions of drilling mud wastes were prepared with a locally fabricated single-screw extruder. Low density polyethylene (LDPE) was the type of polymer selected as matrix for the composites. The mechanical properties of LDPE virgin resin, recycled LDPE, and LDPE containing 2.5wt% and 5.0wt% drilling mud waste-polymer composites has been studied. Yield and tensile strength, percentage elongation, the modulus of elasticity, density, hardness (SHORE D), and indentation were determined for each sample. It was found that drilling mud waste had no significant impact on the mechanical properties of LDPE. As compared to the mechanical properties of unfilled LDPE, drilling mud waste (DMW)-filled polymer composites showed lower yield and tensile strength, % elongation and indentation, while the modulus of elasticity was higher than that of LDPE.

Keywords: Drilling mud, single screw extruder, matrix, mechanical properties and composites

INTRODUCTION

Reinforced thermoplastics comprise of an important group of mouldable plastic materials which are being utilized to an increasing extent in the manufacture of small load bearing components. Most thermoplastic materials may be reinforced by the incorporation of either particulate or fibrous filters by the incorporation of either particulate or fibrous fillers. Particulate fillers such as chalk, talc and mica are cheap and improve a number of properties, notably dimensional stability but do not strengthen the material to an appreciable extent. They are really non- reinforcing fillers. Other particulate fillers such as flake glass, metal powder, etc., may give an appreciable reinforcement. However, fibrous fillers consisting of short discontinuous fibres may be utilized more effectively to give a high degree of enhancement of stiffness and strength, together with improved dimensional stability and elevated temperature performance.

The essential characteristic of reinforced thermoplastics materials is that they may be shaped by melt fabrication techniques, that is injection moulding and to a lesser extent, extrusion, blow moulding and thermoforming. In principle, the thermoplastic suffers no chemical alteration during the processing cycle and may thus be reprocessed several times. In practice this ideal is seldom approached since the materials are affected by thermal, mechanical and oxidative degradation. Generally, the most serious limitation of thermoplastic based materials is their lower thermal stability.

Nowadays, plastic products are receiving more and more attention due to their versatile applications. However, disadvantages of the plastic arrive when they are required to accept high forces or be stiffer. This is the origin of the production of plastic composites that contain both polymer matrix and organic or inorganic reinforcement.

In the related literature, it has been reported that most polymer composites involve fibres reinforcement, for instance, bamboo fibres (Chen et al, 1998), fibers from oil palm empty fruit bunch (Rozman et al, 2003), aspen fibres (Coutinho et al, 1997 and 1998). These composites bring about greater mechanical properties than those of polymers alone especially the Young's modulus and Flexural modulus (Chen et al, 1998; Rozman et al, 2003; Countinho et al,1997 and 1998; Marcovich Ct 81, 1999).

Furthermore, the application of coupling agents such as maleic-anhydride grafted polypropylene (MAPP) (Chen et al, 1998; Rozman et al, 2003; Countinho et al, 1997 and 1998; Marcovich et al, 1998) or Silane coupling agent Countinho et al, 1997 and Malda and Kokta, 1991), have received much attention on the account of their effectiveness in intensifying phase compatibility between the polymer matrix and reinforcement loading to preferred mechanical properties of the composites.

In general, solid additives such as fillers and reinforcing agents improve impart strength, flexural strength, tensile strength and heat distortion temperature of polymers (Katchy, 2000). Thus polyester with a modulus of 2-4 GPA and a tensile strength of 20-7O Mpa when reinforced with short glass fibres yields composites of modulus 10GPa and tensile strength of 11OMPa. The ratio of the modulus of filled polymer to that of unfilled polymer at the same strain is known as the enhancement factor. For a given system the enhancement factor depends on the amount and type of filler that is on shape of particles, length to diameter ratio and orientation of the fibres (Katchy, 2000).

Generally, fine particles when well dispersed improved the impact behaviour. Inadequate dispersion of filler particles can be a possible cause of crack initiation and feature in service. The enhancement factor decreases with increasing strain (Katchy, 2000) so that in assessing filler, modulus measurements should preferably made at strains to which the material is likely to be subjected.

The physical and mechanical properties of polymer/filler composites are known to be dependent upon the dispersion and size of fillers in polymer matrices (Tjong et al, 2008). The study shows that a uniform dispersion of fillers in polymer matrices usually leads to enhanced properties, but poor dispersion may result in a drastic deterioration of properties. Materials design or selection method is considered as an effective route to control the dispersion of fillers in polymer matrices. This method is based on proper selection of appropriate polymeric materials of the composites such that reinforcing fillers are dispersed uniformly in desired phases. A typical example is the dispersion of filler particles in the carbon black reinforced polyethylene/polystyrene composites (Tjong et al, 2008). In this system, carbon black particles are found to disperse either within PS or PE phase or at their inter phase region. According to the study, such dispersions of carbon black particles greatly affect the electrical properties of the mechanical properties of the composites (Tjong et at, 2008). This issue can be solved by using semi-crystalline homopolymers, such as polyethylene, as the matrix of the composites (Tjong et al, 2008).

Semi crystalline polymers generally have crystalline and amorphous phases and their morphology can be tailored by controlling the crystallization conditions. (Tjong et al, 2008).

MATERIALS AND EXPERIMENT METHODS

Materials/Equipment Used

1. A locally fabricated single-screw extrusion machine, which have the following parameters;
   a. Screw shaft diameter of 35mm
   b. Screw shaft length of 600 mm
   c. Main motor speed of 1450rpm
   d. Maximum and minimum motor variable speed of 900rpm and 600rpm respectively.
   e. Maximum and minimum speed of screw shaft of 150rpm and 100rpm respectively, was employed.

After the fabrication and assembly, four different samples of LDPE was processed from the machine in order to test run it.

A cooling bath and puller was also incorporated.

2. Low density polyethylene resin produced by that polyethylene (1993) Co. LTD was purchased from Ceeplast Industries LTD along side with a recycled LPDE grade.
3. Drilling-mud waste which serves as filler was collected from petroleum drilling site at Portharcourt, Rivers State of Nigeria.

   Other materials include glycerol (processing aid), digital electric weighing balance and oven.

SAMPLE PREPARATION

Four samples (virgin, recycled, 5gDM and 1OgDM- filled LDPE composites) were processed with the extrusion machine. The drilling mud waste was first dried in an oven at about 100°C for 8 hours at the FUTO Erosion Control Laboratory. The dried mud is then sieved with a mesh size of 75μm (or 0.075mm) in diameter. The table below shows the formulation of the samples.

Table 1. Tray Formulation of Samples

Tray ID	Drilling–mud waste (wt %)	LDPE (Virgin) (wt %)	Recycled LDPE (g)	Glycol (ml)
A	0	100	0	0
B	0	0	200	0
C	5	100	0	2
D	10	100	0	2

Extrusion Process

The materials are weighed out in a container where it is being mixed with glycerol (processing aid). The composites were produced with the FUTO Polymer Engineering Standard single screw extruder. The extruder is put on and allowed to heat for l½hours to attain the required melting temperature. The extrusion machine has two indicator heater bands having temperature zones of 130°C and 150°C. The materials are then poured into the hopper of the materials and then extruded into a cooling bath and finally drawn by a puller.

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The screw provides the necessary and needed shearing action and equally helps in the thorough mixing of the components before being extruded. It is noted that after extruding a sample composition, the extruder is flushed with virgin resin to remove every trace of the composite mixture that may still be locked in the barrel.

Density Measurement

The density of a polymer composite is a very important property in the polymer industry as it has a direct relationship to the load bearing ability of the polymer as well as the cost. The measured density of a polymer is the apparent or bulk density. The extruded samples were cut into three (3) samples each at specific length, the length and the width dimension is being measured using a metre rule and a dial gauge to measure the thickness the thickness. The weight of the samples was also measured with a digital weighing balance.

The density (p) is therefore given as;

$$(p) = \text{mass (g)/volume (cm}^3\text{)}$$

See results in Table 4.1. This measurement was made at the Polymer and Textile Engineering Laboratory.

Tensile Test (ASTM D 638-95)

Various tests were done on the dumb bell test piece samples at Socotherm Nigeria Limited, Onne, and Portharcourt; in order to determine various mechanical properties on the composite.

The test was determined by MATEST Elongation and tensile machine at 23±2°C using ASTM D 638, which contains the following (I) Tensile strength, (ii) Modulus, (iii) Elongation.

Prior to the testing, the thickness, and width of each sample were measured at three different points along the narrow section and the average value of each section recorded. The values were keyed into the computerized machine as sample was tested; each sample was placed in the grips of the testing machine. The extending load increases within the limit permitted by the machine. The speed of the test machine is set at 50mm/mm before starting the machine. As the load was applied, the load- extension curves were displayed on the monitor of the computer to which the machine is connected. The load-extension graphs were then converted to stress-strain graphs (see section 4).

From the data obtained during the test, it is possible to calculate the elongation, and tensile strength at yield and break point.

$$Tensile\ strength = \frac{Maximum\ load}{Original\ Cross-sectional\ area}$$

$$Modulus\ of\ elasticity = \frac{Change\ in\ stress}{Change\ in\ strain}$$

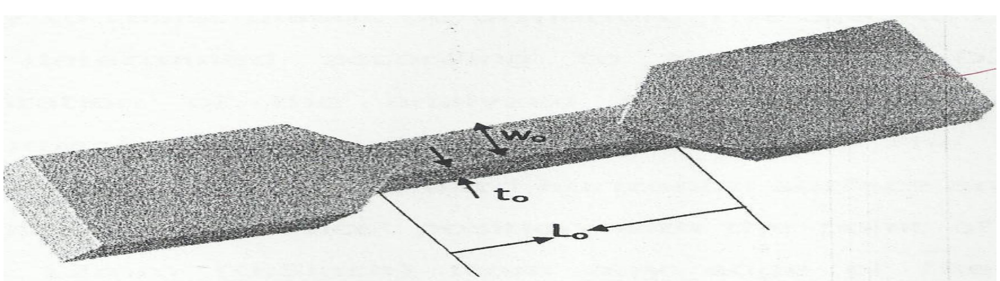

Fig 3.1: Dumbell Shape of Test Sample

L_o = original gauge length

t_o = thickness

w_o = width of the sample (narrow section)

Indentation Test

This indentation test (penetration) test was also carried out in Socotherm Nig LTD. The indentor was 250g metal rod to which an additional weight can be attached. A metal pin with a flat face was fitted at a lower end of the rod. The total mass of the assembly was 2500g corresponding to a pressure of iON/mm2. The temperature condition of the test was about 25°C. The test piece was conditioned for one hour at the test temperature. The indentor (without additional weight) was carefully lowered on the test piece and allowed to stabilize within 5 seconds.

Following is the addition of the additional weight to the indentor and the depth of penetration was read from the penetrometer. See table 4 for test results

RESULTS AND DISCUSSION

Hardness Test (ASTM D2240)

The test was carried out at Socotherm Nigeria Limited, Onne, Portharcourt. Hardness is a measure of the materials ability to resist plastic deformation. The SHORE D hardness value was determined according to the ASTM D2240 by initial indentation of the analyzed materials. Durometer was the instrument used to determine hardness. The specimen to be tested was placed on a hard horizontal surface and the durometer was held in a vertical position with the point of the indicator at least 12mm (O.5inch) from any edge of the specimen. The presser foot was applied to the specimen as rapidly as possible. The measurement was carried out at three different points along the gauge length and subsequent readings were taken with the given hardness type. The actual result is obtained by evaluating the meah of the three values.

Density Measurement Results

The results of the density measurements of the samples are as shown in table 2 below:

Table 2. Density Measurement Result

Sample	*Density (G/Cm^3)*
UNFILLED LDPE	0.749
RECYCLED LDPE	0.779
2.5% DMW FILLED LDPE	0.815
5.0% DMW FILLED LDPE	0.778

The tables below show the tensile properties which are obtained by evaluating the average of the three different readings for each of the four samples (i.e. unfilled LPDE, three samples were cut and then tested from which the average was obtained).

The tensile properties of the unfilled polymer (Table 3), recycled polymer (Table 4), and the drilling mud/LDPE (Table 5) composites were determined for the stress-strain curves presented in figure 3.1. Generally, the unfilled polymer present superior tensile properties compared to those of the composites as clearly indicated on Table 2.

It can be seen from Table 2 that the tensile breaking strength of the unfilled LDPE resin is the highest, followed closely to it is that of the recycled LDPE resin while the tensile strength of the 2.5% and 5% drilling mud wastes-filled LDPE composites decreases accordingly.

Table 3. Average Materials Tensile Properties

Unfilled LDPE	*1*	*2*	*3*	*Average*
Tensile strength (N/mm^2)	15.00	13.40	14.20	14.20
Yield Strength (N/mm^2)	7.50	8.30	8.30	8.30
Modulus Elasticity (N/mm^2)	29.42	55.24	35.06	39.90
Elongation at break (%)	813.63	721.82	758.14	764.53

Table 4. Mechanical Properties of Recycled LDPE

Recycled LDPE	*1*	*2*	*3*	*Average*
Tensile strength (N/mm^2)	15.70	14.50	14.10	14.10
Yield Strength (N/mm^2)	10.00	8.50	8.60	9.03
Modulus Elasticity (N/mm^2)	75.18	57.18	64.32	65.80
Elongation at break (%)	720	645	710	691.66

Table 5. Mechanical Properties of Drilling Mud filled LDPE of different Loadings

5g DM-Filled	*1*	*2*	*3*	*Average*
Tensile strength (N/mm^2)	10.91	10.00	12.95	11.28
Yield Strength (N/mm^2)	6.39	6.40	7.11	6.62
Modulus Elasticity (N/mm^2)	39.52	51.97	67.34	52.94
Elongation at break (%)	610	550	580	580
10 DM-Filled	*1*	*2*	*3*	*Average*
Tensile strength (N/mm^2)	10.61	9.63	12.91	11.05
Yield Strength (N/mm^2)	7.56	7.70	8.56	7.94
Modulus Elasticity (N/mm^2)	38.40	43.85	56.30	46.18
Elongation at break (%)	627.10	631.00	471.10	576.40

Tensile Yeild Strength

The tensile yield strength of the drilling mud-filled LDPE composites are lower compared to that of the unfilled and the recycled LDPEE as clearly shown in tables.

Modulus of Elasticity

The information represented on the table 5 shows that the drilling-mud filled LDPE composites have significant effect on the modulus of elasticity of the composites. However, that of the recycled LDPE deviated with a higher value compared to the filled Composites.

Elongation at Break

Both percentage reduction in area and the percentage elongation are considered to be measures of a material ductility. Ductility is simply the ability of a material to deform without breaking. Clearly shown on the table, the unfilled LDPE has higher elongation at break values when compared to the recycled polymer and to the drilling mud-filled composites. The percentage elongation at break decreases as the filler content increases.

Hardness Test Results ASTM D2240

Table 6 below shows the shore D hardness value of the unfilled, recycled and the filled LDPE composites, which was determined by initial indentation of analyzed materials. It can be seen from the table that the SHORE D hardness value of the 5% DM-filled compoisites is the highest compared to those of 2.5% DM-filled, unfilled and recycled LDPE. The 2.5% filler content shows lowest hardness value.

Table 6. Shore D Hardness Test Values Sample Result

Sample	*Result*			
	1	2	3	Average
Unfilled LDPE	45	46	44	45.00
Recycled LDPE	45	45	46	45.30
2.5% Content	45	44	45	44.67
5% Content	45	46	46	45.67

Indentation (Penetration) Result

Table 7. Indentation Test Result

Sample	*Result (MM)*			
	1	*2*	*3*	*Average*
Unfilled LDPE	0.13	0.06	0.14	0.110
Recycled LDPE	0.10	0.04	0.04	0.060
2.5% Content	0.04	0.06	0.01	0.067
5% Content	0.14	0.09	0.07	0.100

From Table 7 it can be seen that the unfilled and the 5% DM-Filled LDPE composites have approximately the same indentation depth also higher than those of the recycled and 2.5% DM – filled LDPE composites both of which also have similar penetration depth values.

Table 8. Significant Material Mechanical Properties

Sample / Property	*Unfilled*	*Recycled*	*2.5% DM-Filled LDPE*	*5% DM-Filled LDPE*
Density (g/cm^3)	0.749	0.779	0.875	0.778
Tensile strength (N/mm^2)	14.20	14.10	11.28	11.05
Yield Strength (N/mm^2)	8.03	9.03	6.62	7.94
Modulus (N/mm^2)	39.90	65.80	52.94	46.18
Elongation at break (%)	764.53	691.66	580.00	576.40
Hardness (SHORE D)	45.00	45.30	44.67	45.67
Indentation (mm)	0.110	0.060	0.067	0.100

CONCLUSION

The fabricated single-screw extruder has been test run to produce extrudates of low density polyethylene, recycled LDPE and drilling mud-filled LDPE composites. The drilling mud wastes showed no significant influence on the mechanical properties of low-density polyethylene up to maximum loading of 5wt%. In general, results (see table 8) revealed that the unfilled (virgin and recycled) LDPE showed better tensile properties compared to that obtained when they are filled with drilling mud waste, except their modulus (toughness) which deviated slightly as the unfilled recycled LDPE displayed highest modulus followed by that of the 2.5wt% and 5wt% filler content respectively. However, both the unfilled and filled LDPE composite showed similar shore D hardness properties, but the indication property of the recycled and 2.5wt% filled LDPE was better than that of unfilled virgin and 5wt% filler content. Finally, it can be postulated that below 5wt% filler content (loading), that the unfilled LDPE resin remains the better choice than drilling mud waste-filled LDPE composites.

REFERENCES

Chen X., Gue Q. & Mi, Y. (1998). Bamboo fibre-reinforced polypropylene composites: A study of the mechanical properties. *J. Appl. Polyrn. Sci.,* 69, 1891-1899.

Coutinho, F. M. B & Costa, T. H. S (1999). Performance of polypropylene-wood fibre composites. *Polymer Testing*, 18, 581-587.

Felix J. X. & Gatenhoim, P. J. (1991). The nature of adhesion in composites of modified cellulose fibres and polypropylene. *J. AppI. Polym. Sci.,* 42, 609-620.

Hull, D. & dyne T.N (1996). *Introduction to composite materials.* Cambridge: Cambridge University Press.

Jack, R.V. (1986). "*Composite Materials and their use on structures.*" London: Applied science publishers Ltd.

Katchy, E. M. (2002). Effects of Additives on mechanical properties of polymers. *Principles of polymer science.* (pp. 421-422).

Khalid, M., Salmaton, A., Ratnam, C. I. & Lugman C. A. (2008). Effects of Trimethyloipropane triacrylate (TMPTA) on the mechanical properties of palm fibre empty fruit bunch and cellulose fibre biocomposite. *J. Eng. Sci & Tech., 3*(2), 153-162.

Martin, G. (Ed) (1989). "*Encyclopedia of Composite Materials and Components."* Chichester, NY: John Wiley & Sons publisher.

Prachayawarakorn, E. & Anggulalat, K. (2003). Influence of Meranti sawdust aspect ratios and amount of loadings on mechanical and morphological properties and meranti sawdust. *J. Sci. Technol., 25*(5), 595-606.

Tjong, S. C., Liang, G. D. & Baso, S. P. (2008). Effects of crystallization on dispersion of carbon Nanotubes and Electrical properties of polymer Nanocomposites. *J. Polym. Eng. Sci.*