Innovative Systems Design and Engineering
ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online)
Vol.9, No.7, 2018

Comparison of Reinforcement Loading on the Mechanical and Physical Properties of Palm Trunk Ash and Polyethene Composites

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Abstract
A comparison experiment of reinforcement loading on the physical and mechanical properties of palm trunk ash and polyethene composites was carried out. The effect of physical and mechanical properties of reinforced low density polyethylene of both virgin and recycled with palm trunk ash was compared using tensile test, hardness test, flexural test and micro structural test determination. The equipment used in determining physical and mechanical properties of the composites materials include metal mould, sieves, digital weighing balance, hack saw, grinding machine, tensometer, universal material tester, digital Rockwell hardness tester and optical micro structural microscope. The matrix materials used for the formation of the composites are the virgin and recycled low density polyethene and palm trunk ash was used as filler material. The composites were prepared using percentage weight of 0%,10%, 20%, 30%, 40% and 50% of palm trunk ash. The conversion of waste materials to a valuable product was the major target of the author and the results showed that palm trunk ash (PTA) can be used as a reinforcing material on polymeric matrices of both virgin and recycled polyethene. The results of the RLDPE-PTA and VDPE-PTA showed that the virgin material was more effective than the recycled material and the quality of the recycled composites can be increased with an increase in the PTA. The Palm trunk ash at 50% increases the tensile strength thereby increasing the brittleness of the material and reducing the ductility. The tensile strength of VDPE-PTA and RLDPE-PTA obtained showed that proper mixture of palm trunk ash and low density polyethene composite are good engineering materials for reinforcement loading. The increase in PTA also decreases the flexural strength of the composite materials which shows that the 0% PTA composite materials have the highest flexural strength. It was also observed that the melting point of the composite materials increase with increase in palm trunk ash of both VDPE-PTA and RLDPE-PTA.
Keywords: Comparison, Reinforcement, Properties, Palm Trunk Ash, Polyethene, Composites

Introduction

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined will produce a material with characteristics different from the individual parent components (Agbede and Manasseh, 2009).

A composite material is a microscopic or macroscopic combination of two or more distinct materials with a recognizable interface between them. In a composite material the constituents do not dissolve or merge completely in one another. Normally the components in a composite material can be physically identified and they exhibit interface between one another. Soft particles like saw dust, rice husk flour, baggase ash, and sawdust and rice husk ash can be dispersed in a harder matrix to improve machinability and reduce coefficient of friction (Igboanugo, 2011)

The use of composites started many centuries ago. Abdullah, et al (2011) produced epoxy-fly ash composites at high filler loading using fly wheel ash particles. They found that as the Fly wheel ash particles loading increased the compressive strength of the composites increased while the impact strength reduced.

Ishida and Koenig, (1980) studied the mechanical properties of fiber epoxy composites. The result of the study showed that the addition of fly ash particles to epoxy matrix led to reduction of the density and increase in the modulus of the composites. According to Callister, (2007) rice husk ash is not considered good reinforcing filler in rubber composites due to the large particle size and low reactive functional group at the filler surface. The reinforcing effect of rice husk ash is not as good as silica and carbon black, but is only comparable to calcium carbonate ($CaCO_3$).

Cooke, (1990) compared the suitability of silica particles and rice husk ash particles for embedding composites in electronic devices. In his study he found that silica filled epoxy composites had better tensile strength than the rice husk ash filled epoxy composites but the mixing viscosity, water absorption and coefficient of thermal expansion were better than the silica filled composites.

According to Guth, (1945) rice husk floor is not good reinforcing filler for polymer composites but can be utilized as biodegradable filler in polymeric materials to minimize environmental pollution. They found from the

study of mechanical properties of polypropylene composites that addition of rice husk flour decreased the mechanical properties of the composites due to poor interfacial bonding between the matrix and the filler and holes formed in the microstructures because of pulling of filler particles in the matrix.

Composites materials have become important engineering materials all over the world because of the unique properties they offer when compared with polymer, metals or alloys. As a result most research and development are focusing on the development of composite materials. Polymer composites have received the attention of researchers because of low strength, hardness and wear of plastics or polymer for most engineering applications. Polymer composites are now being used in both indoor and outdoor structural applications in housing, construction, auto-industry, aerospace (Isiaka, and Temitope, 2013).

Polyethylene or polythene is the most common plastic. The annual global production is around 80 million tonnes. Its primary use is in packaging (plastic bags, containers including bottles, etc.). Many kinds of polyethylene are known, with most having the chemical formula $(C_2H_4)_n$. Polyethylene is usually a mixture of similar polymers of ethylene with various values of n(Aku, et al, 2011)

Low-density polyethylene (LDPE) is a thermoplastic made from the monomer ethylene. It was the first grade of polyethylene, produced in 1933 by Imperial Chemical Industries (ICI) using a high pressure process via free radical polymerization. Its manufacture employs the same method today. The EPA estimates 5.7% of LDPE is recycled. Despite competition from more modern polymers, LDPE continues to be an important plastic grade (Josmin, et al, (2012).

MATERIALS AND METHOD

The materials used for this research work were the virgin low density polyethene (VLDPE), the recycled low density polyethene (RLDPE), palm trunk ash and equipment used were metal mould, sieves, digital weighing balance, hack saw, grinding machine, tensometer, universal material tester, digital Rockwell hardness tester and optical micro structural microscope. The VLDPE was sourced from the Onitsha main market. Pure water sachet known as Recycled low density polyethene (RLDPE) used were collected around the refused dump at the Faculty of Engineering, Enugu state university of science and technology, Enugu, Nigeria. The filler material, (Palm trunk) was got from felled palm tree and was cut into palates and was further reduced to strands of 3 to 4 mm and then grounded and sieve.

Fig 1: Cutting off of the palm trunk bark at Agbani

Fig 2: Pallets of palm trunk

Fig 3: Grounded palm trunk (palm trunk ash).

Fig 4: Mould used for the production of the composites

The testing techniques for the composite materials required to determine tensile, hardness and flexural strength. The patterns were made according to the required dimensions of the test samples. The molds were constructed to within ± Imm to give allowance for machining if necessary and the surfaces were rubbed with wax releaser (groundnut oil) to ensure easy removal of the materials.

The measured volume of VLDPE were mixed in a container and stirred at low speed for 10 minutes until it became uniformly melted and in full liquid form, removed from the furnace and pour the palm trunk ash filler which will immediately make the mixture to foam. It is allowed to settle and then poured into the mould. Before pouring into the mould, we ensure that the mould is properly lubricated with groundnut oil for easy removal of materials from the mould.

Physical Test (Micro structural Observation)

The test was carried out at material and metallurgy laboratory, Enugu state university of science and technology (ESUT), Enugu state, Nigeria. An optical micro structural microscope with magnification 200 was used to determine the micro structural view of the composite of different sample. The microscope is connected to a computer where the microstructure will be viewed on the computer screen by the help of software and then printed out or copied to an external drive for analysis. The six VLDPE-PTA composite samples of different composition and six RLDPE-PTA composite samples were loaded in the specimen chamber one after the other and the views were collected and saved in the computer accordingly.

Tensile Strength of the Samples

Tensile testing of the samples was done at the Strength of Materials Laboratory, University of Nigeria, Nsukka. Hounsfield (Monsanto) tensometer was used in performing the tensile test. The virgin low density polyethene-palm trunk ash composite and the recycled low density polyethene-palm trunk ash composites were cut into tensile test samples in accordance with the ASTM standard D638. Turning on the Hounsfield tensometer and the computer connected to it, loading the correct beam in the Hounsfield, attaching the movable and fixed jaws, setting the mercury indicator, and ensuring that the ends of the test piece were fitted into the grip of the tensometer. Tensile forces were applied gradually by turning the hand wheel of the rotating drum. Turning of the hand wheel of the rotating drum pulled the samples until fracture occurred.

The deformations were obtained from the load-extension curve. The traced load- extension curve was converted to stress-strain values. Other tensile properties like elongation at fracture, tensile strength and young modulus were determined from this stress- strain curve

Hardness

The hardness test was done at the material and metallurgy departmental laboratory, Enugu state university of science and technology, Enugu state, Nigeria. An automatic electric powered Rockwell hardness testing machine was used to determine the hardness value of the VLDPE-PTA composite and RLDPE-PTA composites. Switching on the machine, selecting the desired load of 30kgf,placing the surface of the specimen to be tested on the anvil of the machine and releasing the indenter of the machine from the lever until it touched the specimen making a green to be shown to indicate test zone specimen. Pressing the test button and there was automatic indentation of the specimen by the conical shaped indenter of the Rockwell tester.

At the end of the indentation a red light showed “read” and instantly reading was directly done from the dial indicator.

Flexural Strength

The flexural strength test was done at the material and metallurgy departmental laboratory, Enugu State University of Science and Technology, Enugu, Nigeria. Each specimen of dimension 80mm by 40mm by 10mm was placed in the flexural testing machine. The three point flexing and loading arrangement was used in which fracture occurred at the middle. The specimen was flexed and flexural force that fractured the specimen at the middle was read from the scale of the machine. The flexural strength and strain was calculated using equation 1 and 2.

$$\text{Flexural strength}(Fs) = \frac{Fl}{bd^2} \quad \text{(Ishiaka and Temitope, 2013)} \qquad 1$$

Where ,

l = gauge length (mm)

b = breadth (mm)

d = thickness (mm)

Fs = flexural strength.

$$\text{Strain } (\varepsilon) = \frac{6sb}{l^2} \quad \text{(Ishiaka and Temitope, 2013)} \qquad 2$$

Where,

s = deflection
b = breath
l = guage length

Thermal Properties

This test was carried out at foundry workshop, faculty of engineering, Enugu state university of science and technology, Enugu state, Nigeria. This was done using a fabricated furnace. The six samples of the VLDPE-PTA composites were cut into the same size and placed in the furnace at 0^0C and turned on. The furnace is checked with the interval of every 4^0C to know which melts first and the reading is taken accordingly. The same was done for the RLDPE-PTA composites samples of different composition. This particular thermal test was just for the melting point of the composites.

Results and Discussion

The results of the study are presented in the figures below. The results of physical properties like weight, moisture contents, optical micro structural microscope and Mechanical properties and thermal behavior of the VLDPE-PTA composites and RLDPE-PTA composites materials were determined and compared. Optical micro structural microscope showed the comparison of microstructure of the composites and the thermal behavior showed the melting points of the different composition of the composites materials

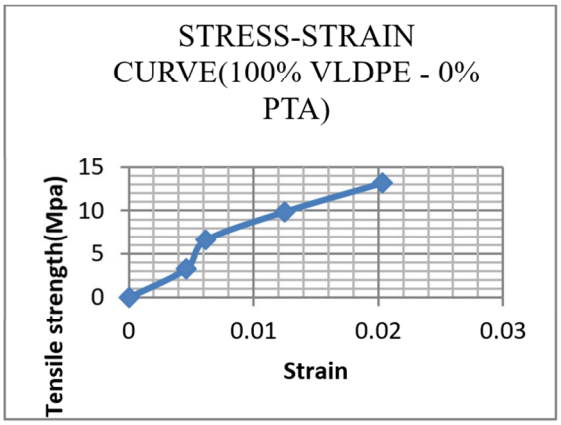

Fig 5a: Tensile test for 100% VLDPE-0% PTA

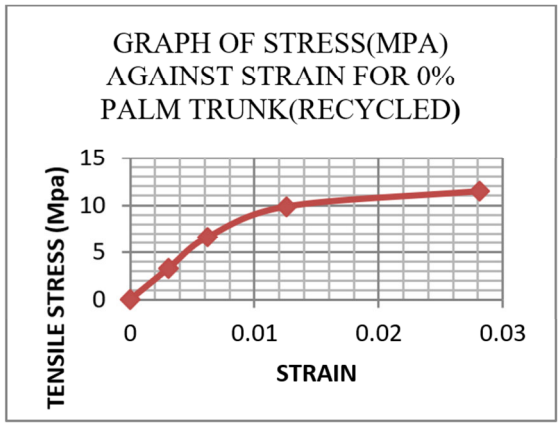

Fig 5b: Tensile test for 100% RLDPE-0% PTA

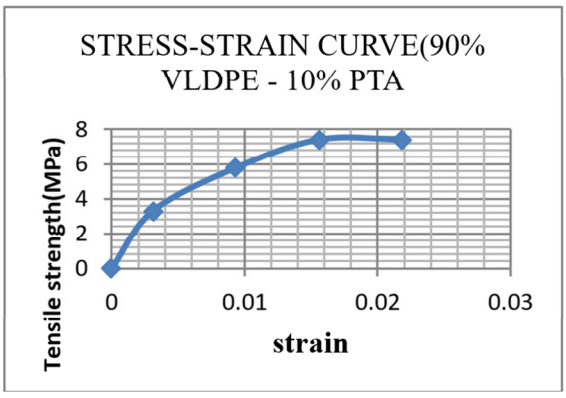

Fig 6a: Tensile test result for 90%VLDPE-10% PTA

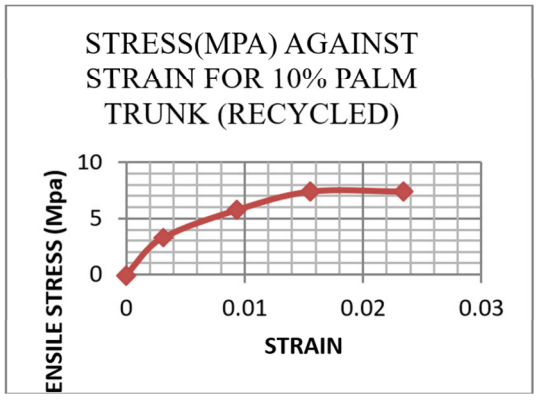

Fig 6b: Tensile test result for 90%RLDPE-10% PTA

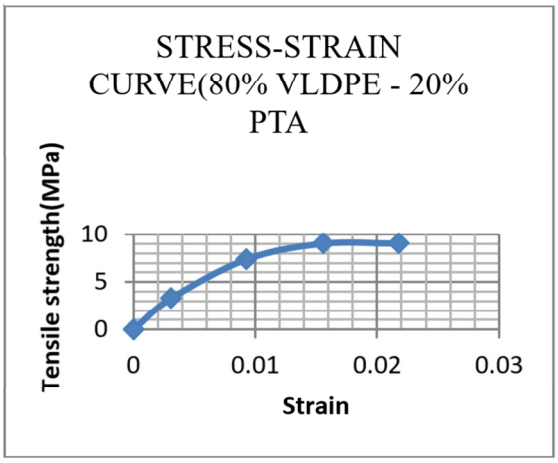

Fig7a: Tensile test result for 80% VLDPE-20% PTA

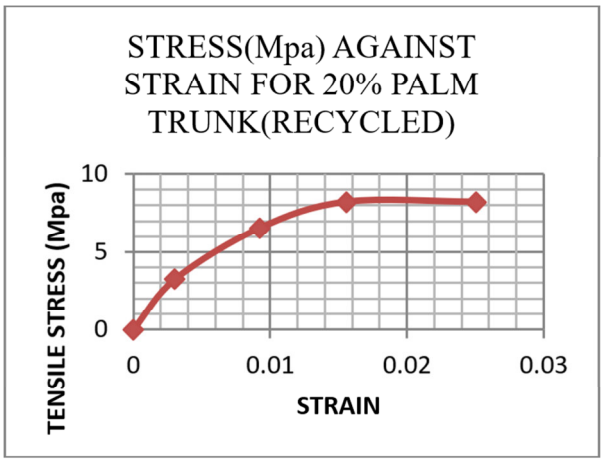

Fig7b: Tensile test result for 80% RLDPE-20% PTA

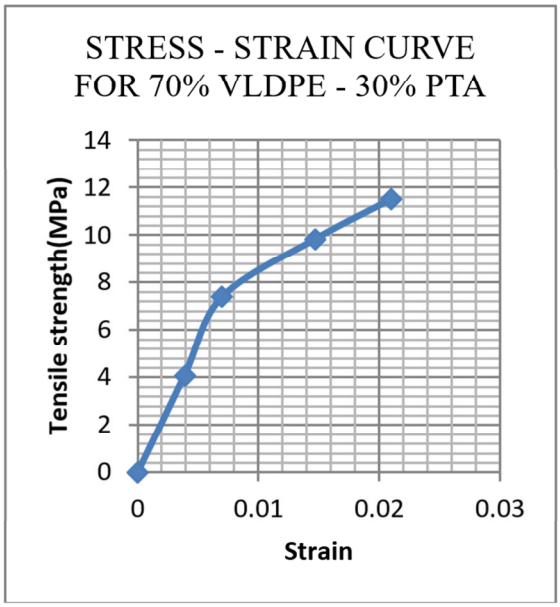

Fig8a:Tensile test result for 70% VLDPE-30% PTA

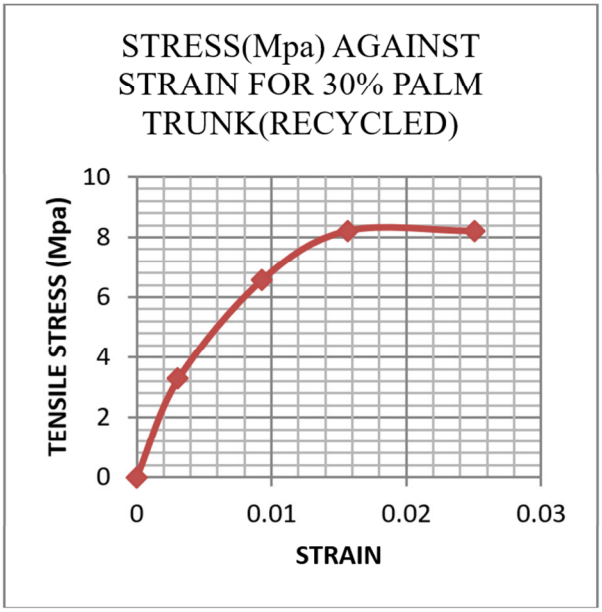

Fig8b: Tensile test result for 70% RLDPE-30% PTA

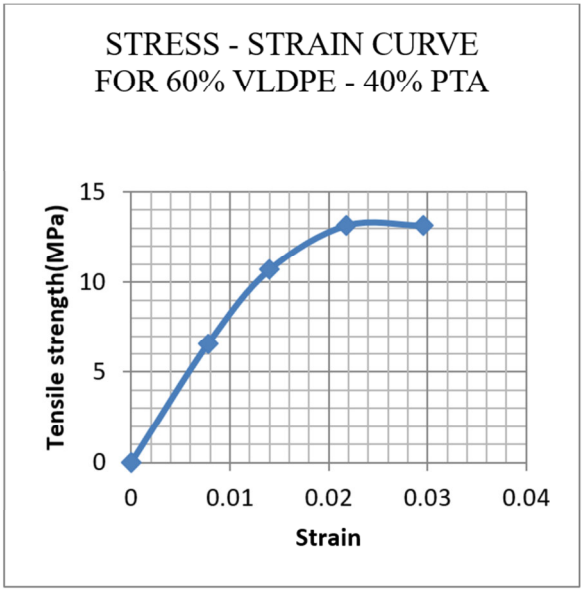

Fig9a:Tensile test result for 60% VLDPE-40% PTA

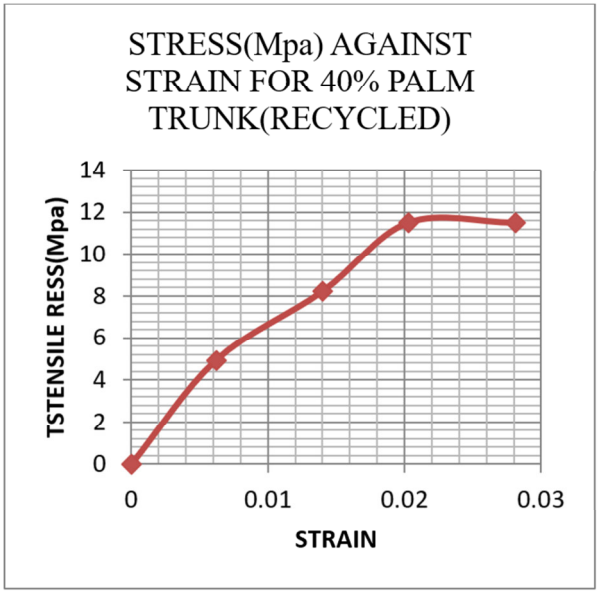

Fig9b: Tensile test result for 60% RLDPE-40% PTA

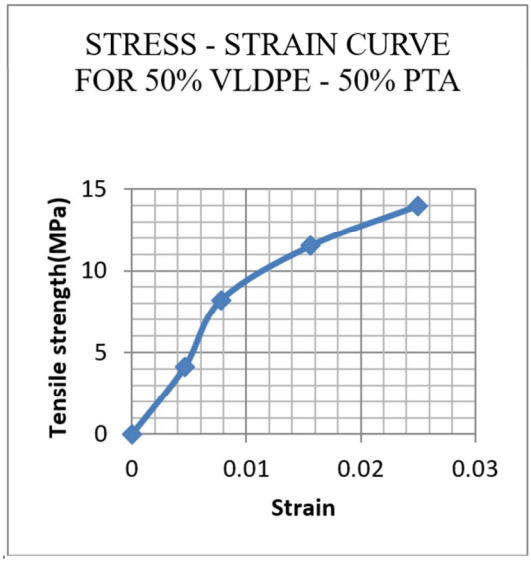

Fig10a:Tensile test result for 50%VLDPE-50%PTA

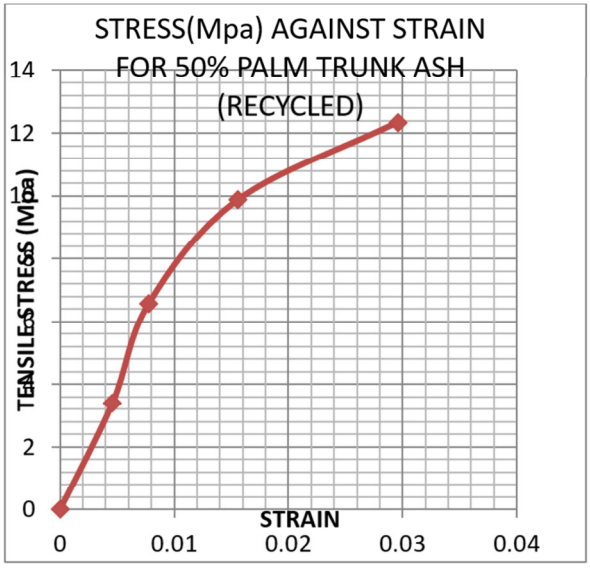

Fig10b:Tensile test result for 50%RLDPE-50% PTA

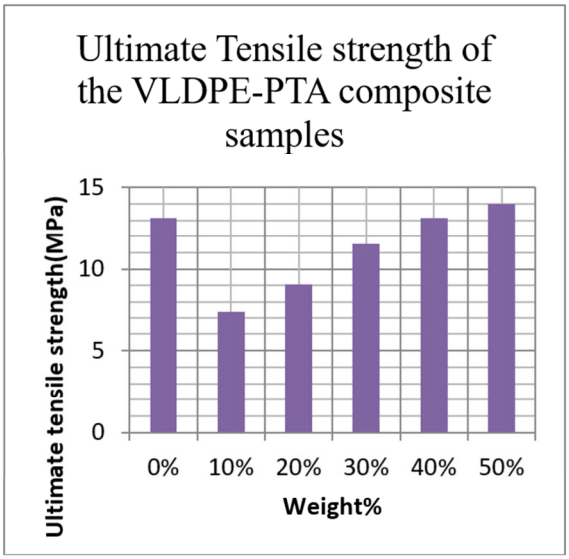

Fig11a: Ultimate tensile strength of the VLDPE-PTA samples

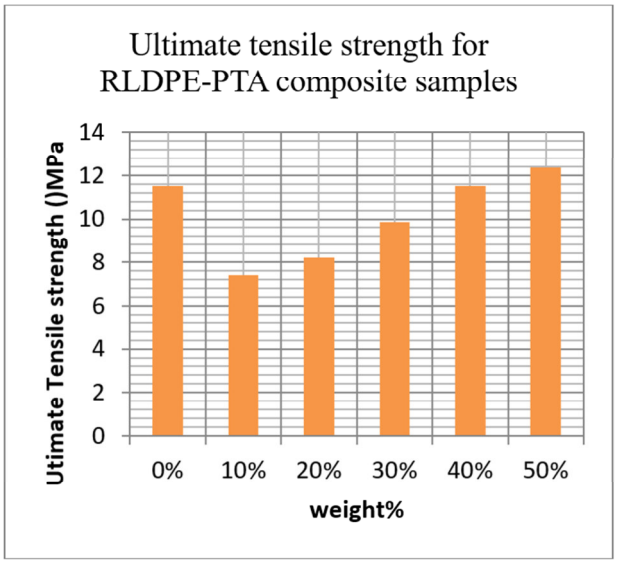

Fig11b: Ultimate tensile strength of the RLDPE-PTA samples

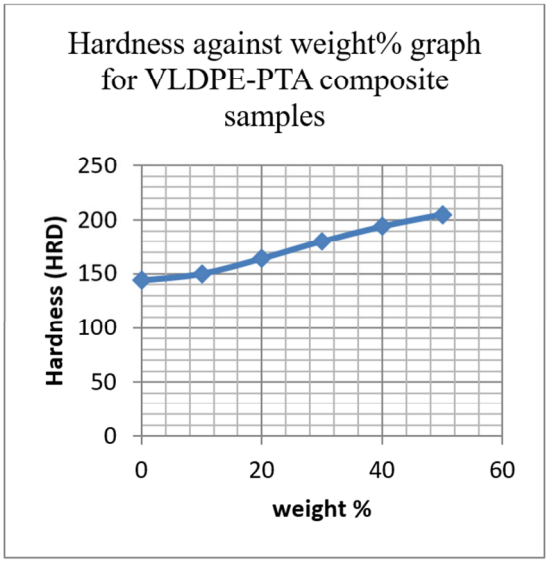

Figure 12a: Hardness test result for VLDPE -PTA composite samples

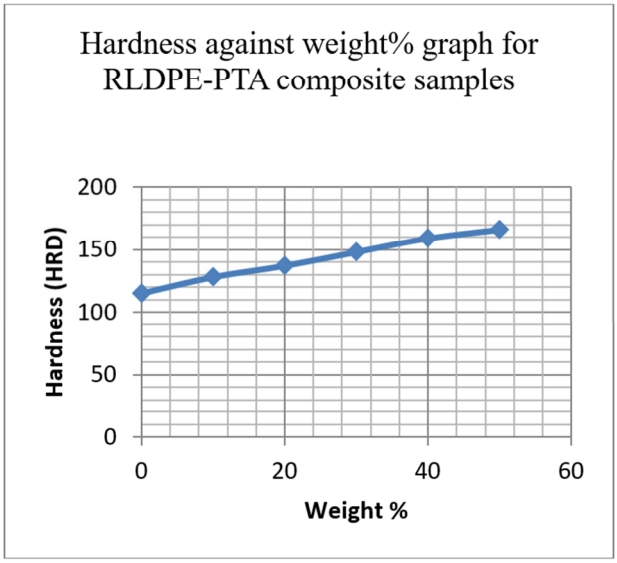

Figure 12b: Hardness test result for RLDPE -PTA composite samples

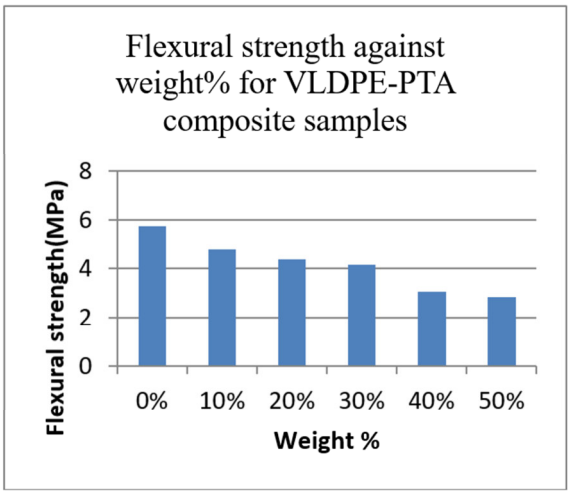

Fig 13a: flexural strength of the VLDPE-PTA composite samples

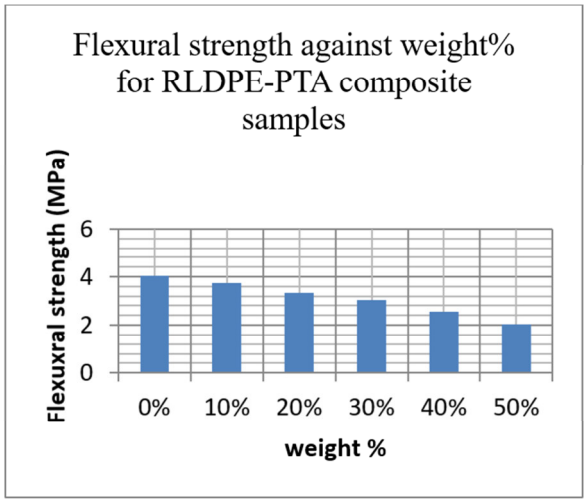

Fig 13b: flexural strength of the RLDPE-PTA composite samples

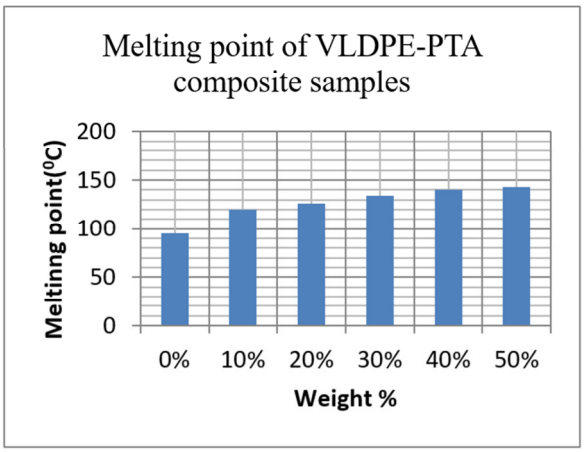

Figure 14a: Melting points of VLDPE-PTA composite samples

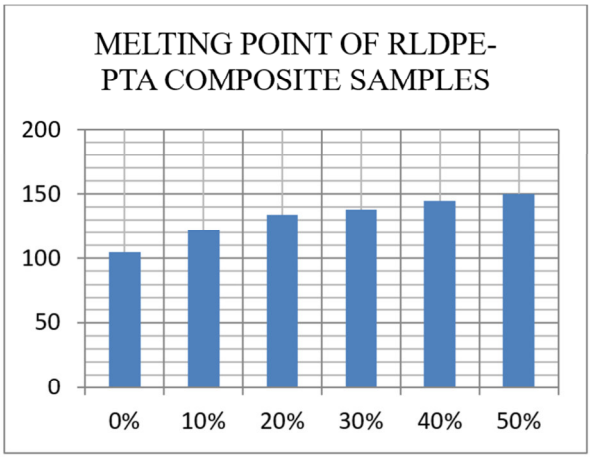

Figure 14b: Melting points of RLDPE-PTA composite samples

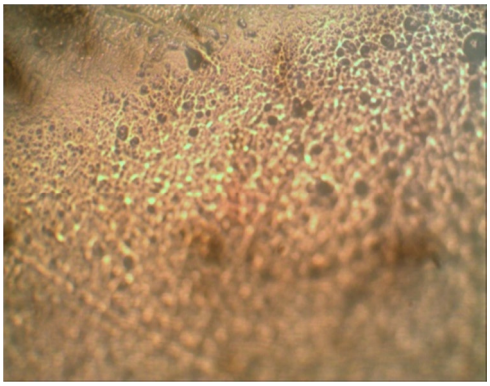

Fig 15a: Micro structural view of 100% VLDPE- 0%PTA

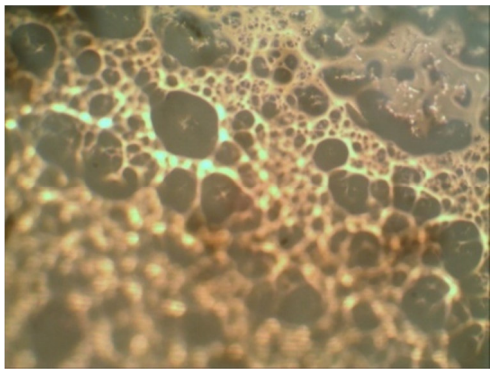

Fig 15b: Microstructural view of 100% RLDPE- 0%PTA

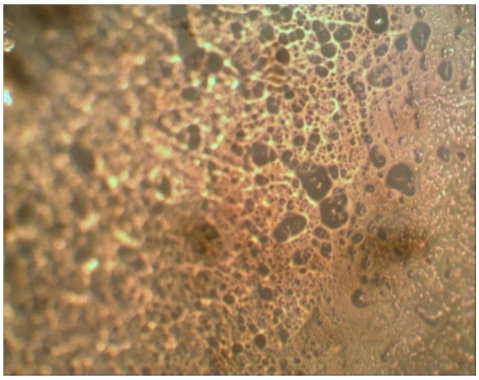

Fig 16a : Microstructural view of 90% VLDPE- 10%PTA

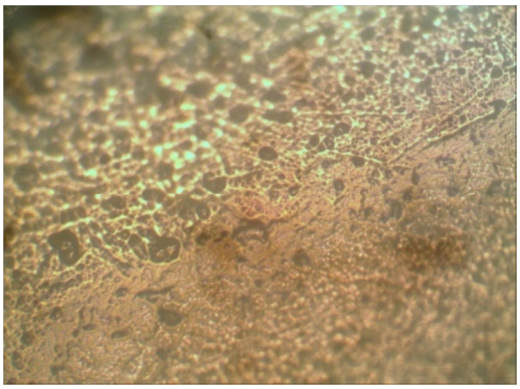

Fig 16b : Microstructural view of 90% RLDPE- 10%PTA

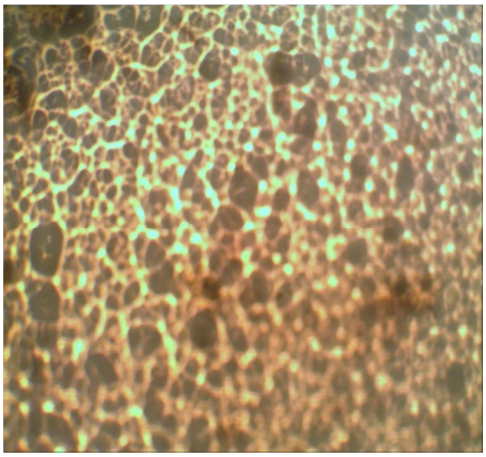

Fig 17a : Microstructural view of 80% VLDPE-20%PTA

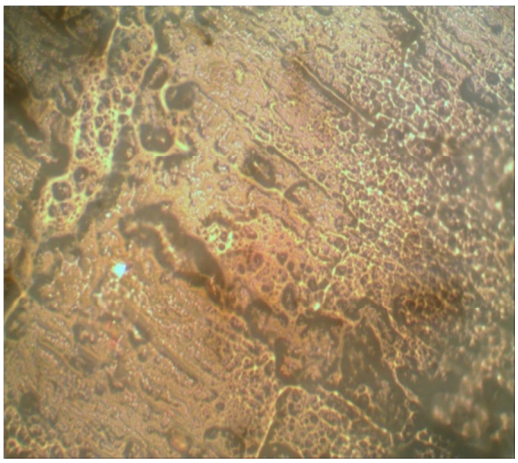

Fig 17b : Microstructural view of 80% RLDPE-20%PTA

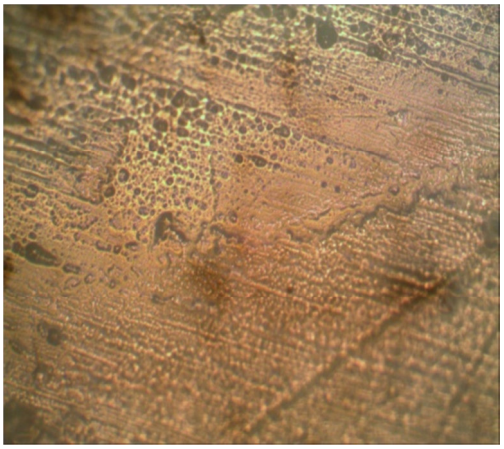

Fig 18a: Microstructural view of 70% VLDPE- 30%PTA

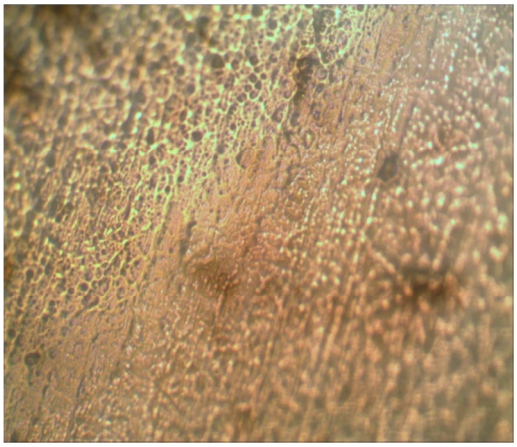

Fig 18b: Microstructural view of 70% RLDPE- 30%PTA

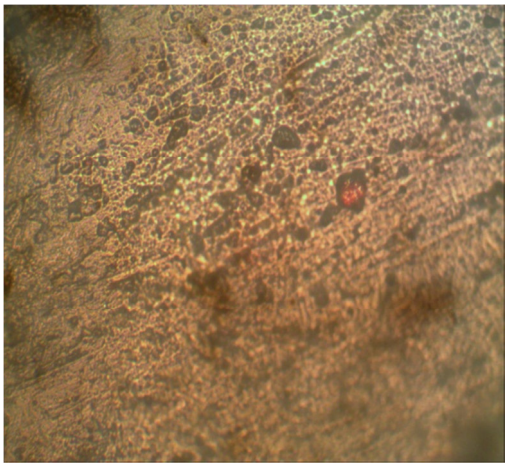

Fig 19a : Microstructural view of 60% VLDPE- 40%PTA

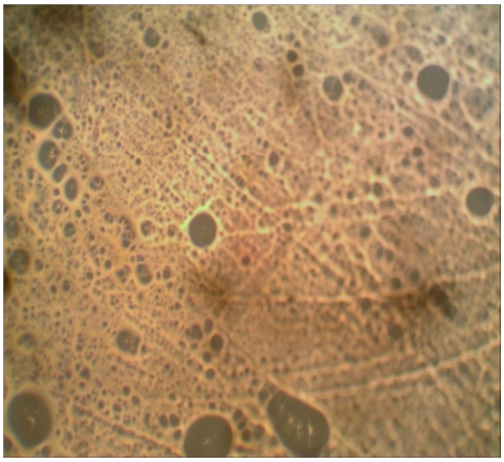

Fig 19b : Microstructural view of 60% RLDPE- 40%PTA

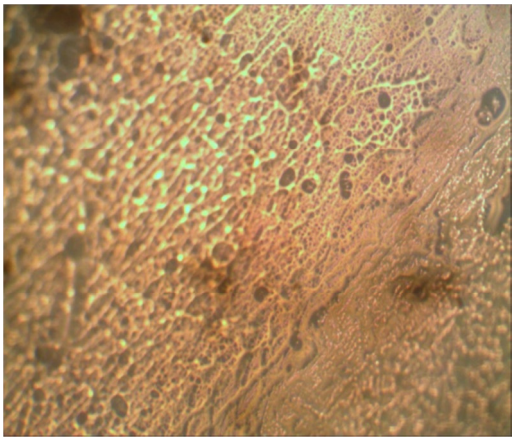

Fig 20a: Microstructural view of 50% VLDPE- 50%PTA

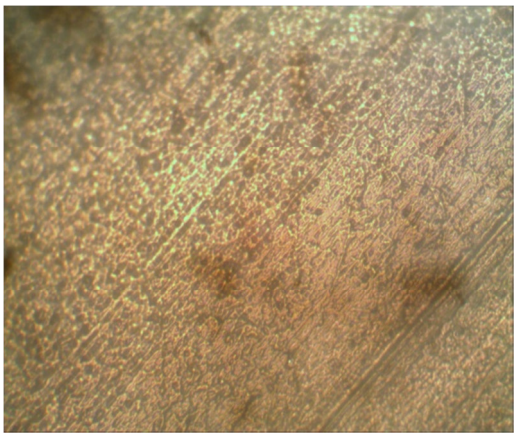

Fig 20b: Microstructural view of 50% RLDPE- 50%PTA

The graphs of tensile stress versus tensile strain of the composites materials of virgin low density polyethene (VLDPE) and recycled low density polyethene (RLDPE) mixed with palm trunk ash were shown from figures 5 to 10. The graphs also shown that the materials were slightly brittle. The reason for the brittleness is because the composites did not sustain large deformations before fracture and some of the stress-strain diagrams had no yield point. The figures 11a and 11b show the ultimate tensile strengths of the two composites materials. The ultimate tensile strengths of the composites with 10%, 20%, 30% and 40% volume of PTA were lower than the 0% PTA while the highest ultimate tensile strength of 13.908MPa was obtained for the VLDPE-PTA and 12.335MPa for the RLDPE-PTA at 50% volume of PTA. The results obtained shown that tensile

strength are affected by volume fractions, degree of adhesion between the filler and the matrix, level of dispersion of the filler and matrix and surface related defects. Tensile strength can decrease with increasing filler content if the filler matrix adhesion is weak and these accounts for the reason why the tensile strength of 10%, 20%, 30%, and 40%volume fraction of PTA were lower than that of 0% PTA. However the reasons for the higher tensile strength of the 50% PTA could be because there was more palm trunk ash in it. This may mean that at a particular volume of palm trunk, the tensile strength will start increasing. Also it might also be because there were strong interfacial adhesions between the palm trunk ash fillers and low density polyethene matrix or better stirring during the production process. The fluctuation of the graph is because manual mixing was used which caused irregular dispersion of the palm trunk ash in the low density polythene. Also, from the bar chart of tensile strength against weight percent for both virgin and recycled low density polyethene, it can be observed that the VLDPE-PTA composites has a higher tensile strength than the RLDPE-PTA composites. This can be because of the impurities that might have been incurred into the low density polyethene during recycling thereby reducing the effective bond between the filler and the matrix.

The hardness value of the composites increases from 144 to 205 for virgin low density polyethene and 115to 166 for recycled low density polyethene with increase in percentage of palm trunk ash as shown in figures 12a and 12b. This increase was due to the hard nature of palm trunk ash. The hardness of the palm trunk ash would not allowed quick penetration of the indenter on indentation. The graphs of hardness against weight of recycled and virgin low density polyethene composite presented that VLDPE-PTA composites is harder than the RLDPE-PTA. This can be due to impurities that must have been introduced during the recycling in the form of gas or any other form. But since the Recycled low density polyethene is cheaper in cost and will as well reduce waste in the streets, it can be observed that with an increase in palm trunk ash, the hardness of the RLDPE-PTA composite will be increased.

The bar chart of flexural strength versus percentage weight of palm trunk ash in figures 13a and 13b show that flexural strength decreased from 4.05MPa to 2.05MPa for recycled low density polyethene as the percentage of palm trunk ash increased. Flexural strength is the ability of material to resist bending, twisting and deformation under load. The reasons for the decrease in flexural strength were poor interfacial adhesion (bonding) between the palm trunk ash and the low density polyethene matrix, distortion in the microstructure caused by addition of palm trunk ash and porous morphology of the palm trunk ash. These defects accounted for lower resistance of VLDPE - PTA composites to flexural force leading to quick rupture.

The figures 14a and 14b presented the graph of melting point against weight and it can be observed that the melting points of this composites increase with increase in volume faction of percentage PTA. This was as a result of the addition of the palm trunk thereby increasing the strength of the bonds.

The figures 15to 20 show the comparison of optical micro structural of the composites of 0 to 50% palm trunk ash on the virgin low density polyethene and Recycled low density polyethene. The physical examination was determined with the aid of microscope.

CONCLUSION AND RECOMMENDATION

The results was shown that palm trunk ash (PTA) can be used as a reinforcing material on polymeric matrices either in virgin state or recycled state. The Palm trunk ash content at a particular volume fraction (50%) increases the tensile strength thereby increasing the brittleness of the material and reducing the ductility.

Also from the comparism between the tensile strength of RLDPE-PTA and VDPE-PTA it can be concluded that although, the virgin material is more effective than the recycled material, that the quality of the recycled composites can be increased with an increase in the PTA.

The increase in palm trunk ash also increases the hardness of the composite. The increase in palm trunk ash also decreases the flexural strength of the composite. These imply that the 0% PTA composite has the highest flexural strength.

The graph of temperature to percentage weight can be seen that the melting point increases with increase in palm trunk ash.

RECOMMENDATIONS

Finer particles such as nano-sized particles should be considered for use in recycled low density polyethylene matrix systems at different filler contents. Other methods should be considered for the production of the composite, at filler contents higher than those used for this experiment (preferably at 10percentage weight increment), to see if the method of production of the composite would provide a better composite material as compared with the compression moulding method used for this experiment.

The degradability test should be carried out for a period of 6 to12 months to determine the level of degradation that may occur over an extended period of time.

Further microscopic test such as Scanning Electron Microscope (SEM) that can analyse the microstructural view of the composite.

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