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Engineering Properties of Palm Trunk Ash and Polyethylene Composites on Reinforcement Loading Effect

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ABSTRACT

The effect on some engineering properties of reinforced low-density polyethylene of both virgin and recycled with palm trunk ash was compared. The matrix materials used for forming the composites are the virgin, and recycled low-density polyethylene and palm trunk ash was used as filler material. The composites were prepared using percentage weight of 10%,20%, 30%, 40%, 50%, 60% and 70% of palm trunk ash. The conversion of waste materials to a valuable product was one of the major targets of the author, and the results showed that palm trunk ash (PTA) could be used as a reinforcing material on polymeric matrices of both virgin and recycled polyethylene. 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 to 50% and decreases on addition. The Palm trunk ash at 50% increases the tensile strength, thereby increasing the material's brittleness and reducing the ductility. The tensile strength of VDPE-PTA and RLDPE-PTA obtained showed that a proper mixture of palm trunk ash and low-density polyethylene composite is good engineering materials for reinforcement loading. The increase in PTA to 50% level also decreases the composite materials' flexural strength, which shows that the 10% PTA composite materials have the highest flexural strength. It was also observed that the melting point of the composite materials increases with an increase in palm trunk ash to a 50% level of both VDPE-PTA and RLDPE-PTA.

Keywords: *Engineering, Properties, Palm Trunk Ash, Polyethylene, Reinforcement Loading*

I. INTRODUCTION

Composite is made from two or more constituent materials with significantly different physical or chemical properties. Combining will produce a material with characteristics different from the individual original components [2].

The individual components remain separate and distinct within the finished structure. The new material may be preferred because of its strength, lighter, or less expensive when compared to traditional materials. The engineering composite materials in ancient times include mortars, concrete, reinforced plastics, metal composite, ceramics, and composite.

According to Callister (2007), rice husk ash is not considered an excellent 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 ($CaCO_3$).

In comparing the suitability of silica particles and rice husk ash particles for embedding composites in electronic devices. It was discovered 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 [5].

Composites materials have become essential engineering materials all over the world because of the unique properties they offer when compared with polymer, metals, or alloys. The result of most research and development are focusing on the development of composite materials.

Polymer composites have received the attention of researchers because of the low strength, hardness, and wear of plastics or polymers for most engineering applications. Polymer composites are now being used in both indoor and outdoor structural applications in housing, construction, auto-industry, aerospace[9].

The annual global production of polyethylene is around 80 million tonnes. Its primary use is in the packaging (plastic bags, containers, including bottles.). 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[3].

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 essential plastic grade [10].

Composites material has become essential engineering materials all over the world because of the unique properties they offer when compared with polymer, metals, or alloys. As a result of this, most research and development are focusing on the development of composite materials. Polymer composites have received the attention of researchers because of the low strength, hardness, and wear of plastics or polymers for most engineering applications. Polymer composites are now being used in both indoor and outdoor structural applications in housing, construction, auto-industry, aerospace. [1].

Natural fillers in the form of fibers of particulate have gained the attention of researchers in recent times as reinforcing materials in polymers, metals, and ceramics. They are ecofriendly, low-cost, low-density materials; they are renewable in a large amount when compared with the artificial fillers[7].

It has been discovered over the years, that effort made to prevent indiscriminate litter of the environment with polymeric and agricultural wastes has been inefficient as these polymeric wastes such as low-density polyethylene can be seen littered in most streets in Nigeria [8]. This call for more effort into the provision of a permanent solution to the problem of polymeric waste disposal in the country and so bring about the motivation for this study.

Therefore, the engineering properties of palm trunk ash and polyethylene composites on reinforcement loading were determined and compared.

II. MATERIALS AND METHOD

The virgin low-density polyethylene (VLDPE), the recycled low-density polyethylene (RLDPE), palm trunk ash are the materials used for the research work, and the equipment used were metal mold, sieves, digital weighing balance, hack saw, grinding machine, tensometer, universal material tester, digital Rockwell hardness tester, and optical microstructural microscope.

The VLDPE was sourced from the Keyeta market in Enugu, Enugu State, Nigeria. The used sachet water known as Recycled low-density polyethylene (RLDPE) were collected around the refused dump at Ogbete main market Enugu, Nigeria. The filler material (Palm trunk) was obtained from a felled palm tree and was cut into pallets and further reduced to strands of 2 to 3 mm, before grinding.

The composite materials are tested from determined tensile, hardness, and flexural strength. The patterns were made according to the required dimensions of the test samples. The molds were constructed to give machining allowance, and the surfaces were rubbed with wax releaser to ensure easy removal of the materials.

The VLDPE measured were mixed in a container and stirred at low speed for 15 minutes in a furnace until it became uniformly melted and ultimately form a liquid, then removed from the furnace and pour the palm trunk ash filler which immediately makes the mixture foam. It was allowed to settle and then poured into the mold. We ensured that the mold was properly lubricated with groundnut oil to remove materials from the mold.

A. Physical Properties

The physical properties or test (Microstructural Observation) was conducted at Material and Metallurgy Laboratory, University of Nigeria Nsukka, Enugu State, Nigeria. An optical microstructural microscope with magnification 200, which was connected to a computer, was used to determine the microstructural view of the composite of different samples. The eight VLDPE-PTA composite samples of different compositions and eight RLDPE-PTA composite samples were loaded in the specimen chamber one after the other, and the views were collected.

B. Tensile Strength of the Samples

The samples were taken to the strength of materials laboratory, University of Nigeria, Nsukka, for tensile strength determination. The virgin low-density polyethylene- palm trunk ash composite and the recycled low-density polyethylene-palm trunk ash composites were cut into tensile test samples per the ASTM standard D638 and a Hounsfield tensometer was used for the test. The Hounsfield tensometer, which was connected to the computer, was used for the test. Tensile forces were applied gradually after loading the sample correctly by turning the handwheel of the rotating drum. Then, turning the handwheel of the rotating drum pulled the samples until fracture occurred. The load-extension curve was used to determining other tensile properties like elongation at fracture, tensile strength, and young modulus.

C. hardness

An automatic electric-powered Rockwell hardness testing machine from a mechanical engineering workshop, Enugu State University of Science and Technology, was used to determine the hardness values of the VLDPE-PTA composite and RLDPE-PTA composites. The surface of the specimen was placed on the anvil of the machine, and the indenter was released from the lever until it touched the specimen, making a green color to be shown indicating the test zone specimen. The test button was pressed, and an automatic indentation of the specimen by the conical-shaped indenter of the Rockwell tester was shown. At that point, close observation of the indented sample of red light showed, and instantly reading was directly done from the dial indicator.

D. Flexural Strength

The test was carried out in materials and metallurgical laboratories at the University of Nigeria Nsukka. The specimens were reducedto70mm by 35mm by 10mm, and the loading arrangement in the machine was chosen, which made fracture occurred in the middle. The specimen was flexed, and the flexural force that fractured the specimen at the middle was read from the machine's scale. The flexural strength and strain were calculated using equations 1 and 2.

$$\textbf{Flexural strength}(\textbf{Fs}) = \frac{\textbf{Fl}}{\textbf{bd}^2} \qquad [9] \qquad \textbf{1}$$

Where,

l = gauge length (mm)
b = breadth (mm)
d = thickness (mm)
Fs = flexural strength.

$$\textbf{Strain } (\boldsymbol{\mathcal{E}}) = \frac{\textbf{6sb}}{\textbf{l}^2} \qquad [9] \qquad \textbf{2}$$

Where,

s = deflection
b = breath
l = gauge length

E. Thermal Properties

Thermal tests were carried out at the foundry workshop, faculty of engineering, Enugu State University of Science and Technology, Enugu State, Nigeria. The test was conducted using a fabricated furnace. The seven 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 was checked with the interval of every 5^0C to know which melted first, and the reading was taken. It was repeated for the RLDPE-PTA composites samples of different compositions.

Fig 1: Palm trunk bark

Fig 2: Strands from pallets of palm trunk

Fig 3: Powdered palm trunk

Fig 4: Composites production mold

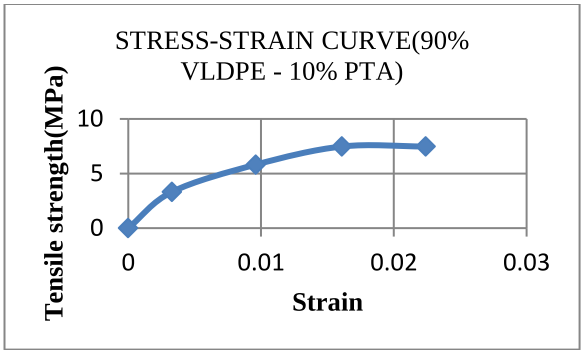

Fig 5a: Tensile test result for 90%VLDPE-10% PTA

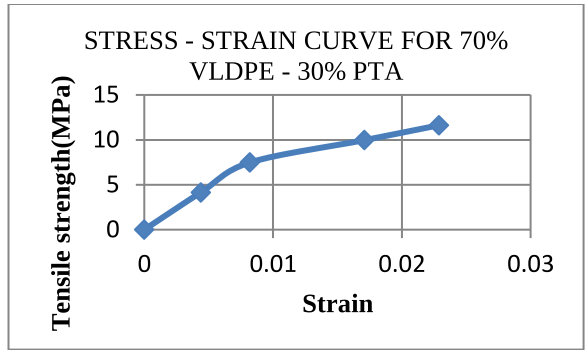

Fig7a: Tensile test result for 70% VLDPE-30% PTA

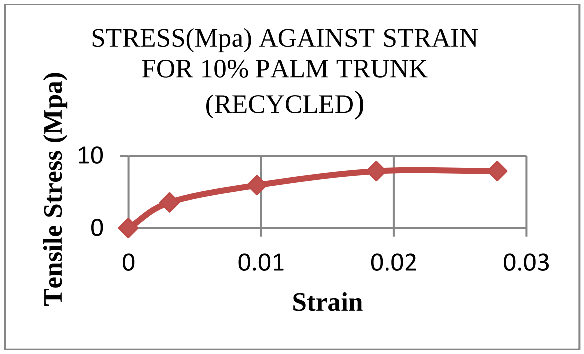

Fig 5b: Tensile test result for 90%RLDPE-10% PTA

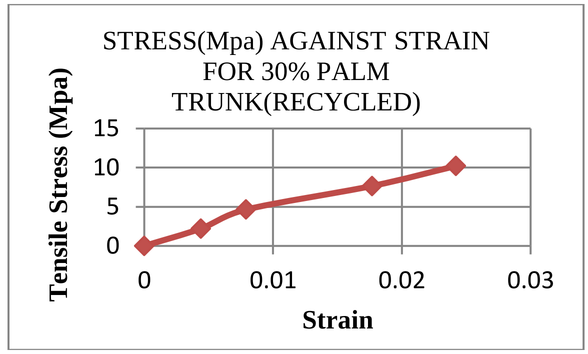

Fig7b: Tensile test result for 70% RLDPE-30% PTA

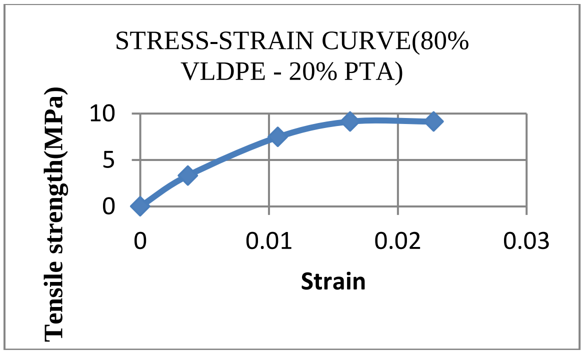

Fig6a: Tensile test result for 80% VLDPE-20% PTA

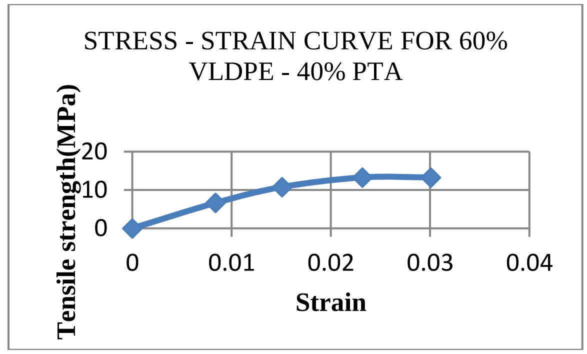

Fig8a: Tensile test result for 60% VLDPE-40% PTA

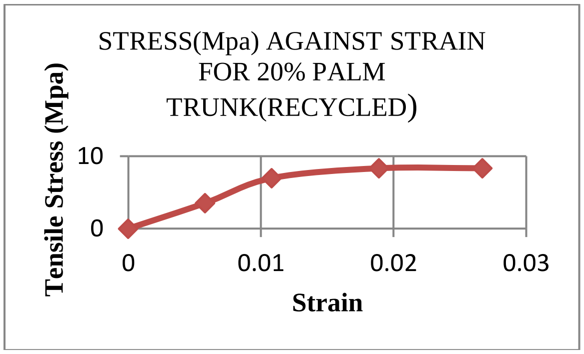

Fig6b: Tensile test result for 80% RLDPE-20% PTA

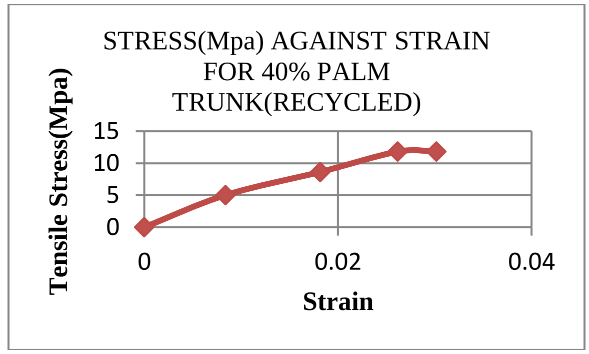

Fig8b: Tensile test result for 60% RLDPE-40% PTA

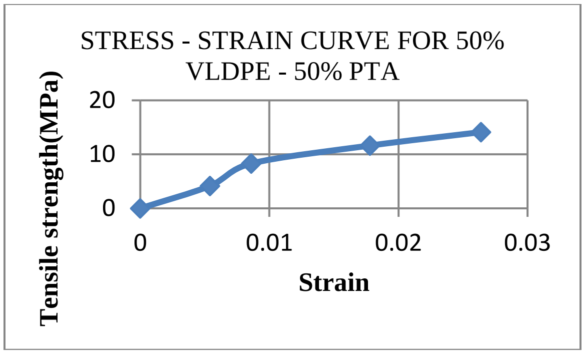

Fig9a: Tensile test result for 50%VLDPE-50%PTA

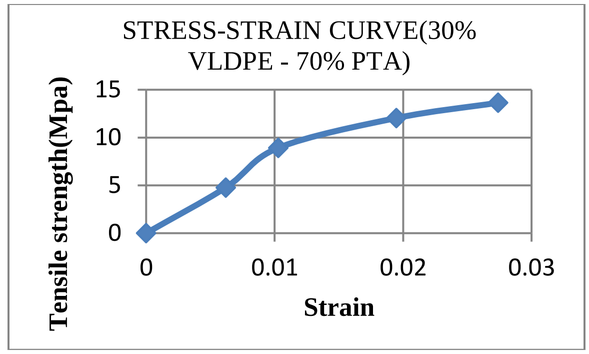

Fig 11a: Tensile test for 30% VLDPE-70% PTA

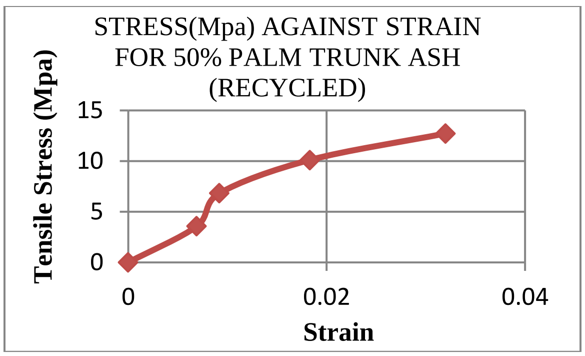

Fig9b: Tensile test result for 50%RLDPE-50% PTA

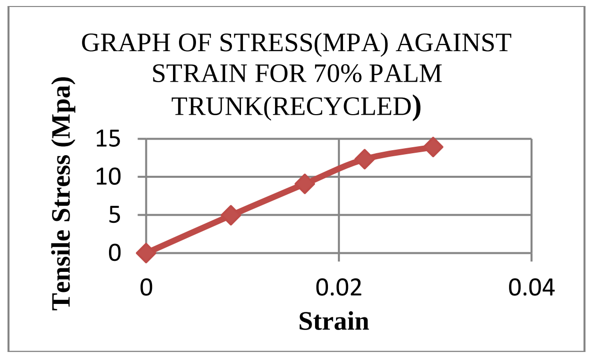

Fig 11b: Tensile test for 30% RLDPE-70% PTA

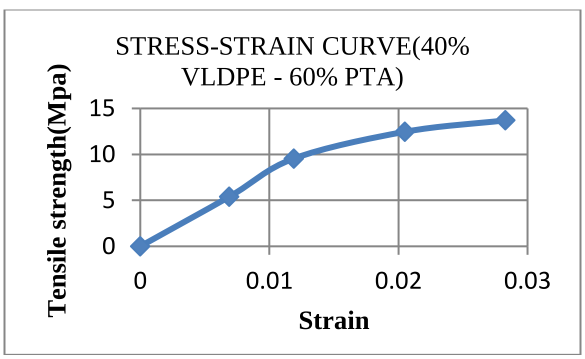

Fig 10a: Tensile test for 40% VLDPE-60% PTA

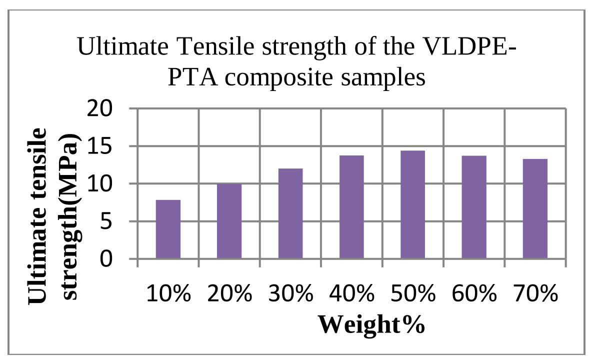

Fig12a: Ultimate tensile strength of the VLDPE-PTA samples

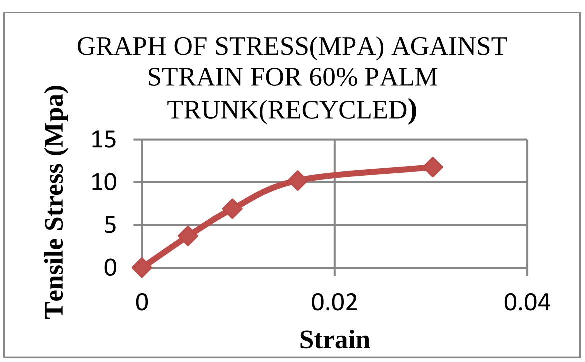

Fig 10b: Tensile test for 40% RLDPE-60% PTA

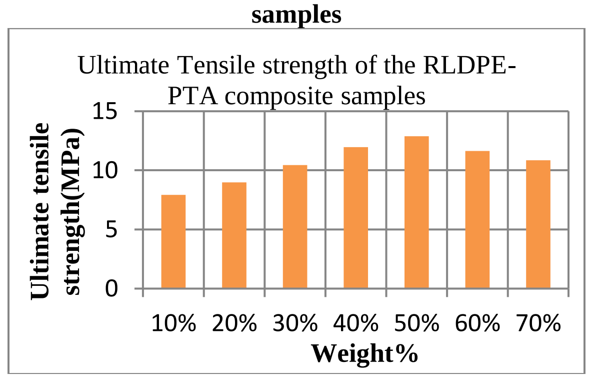

Fig12b: Ultimate tensile strength of the RLDPE-PTA samples

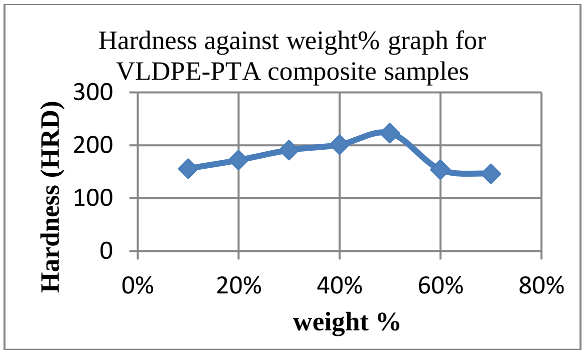

Figure 13a: Hardness test result for VLDPE-PTA composite samples

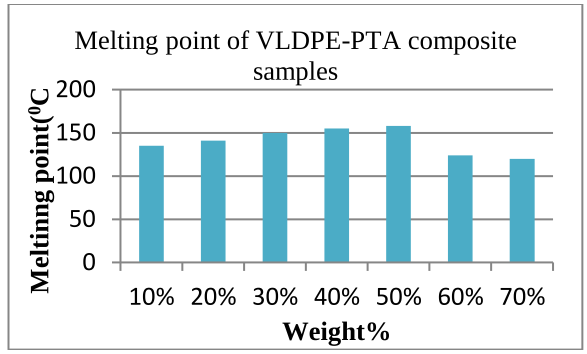

Figure 15a: Melting points of VLDPE-PTA composite samples

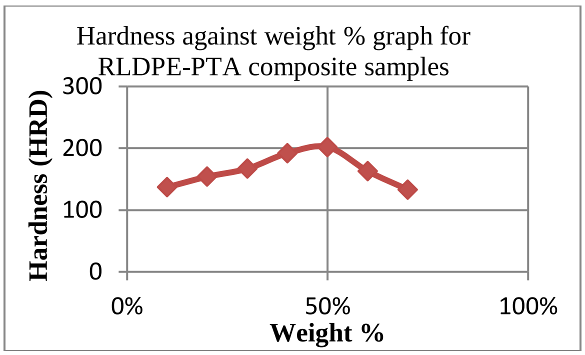

Figure 13b: Hardness test result for RLDPE-PTA composite sample

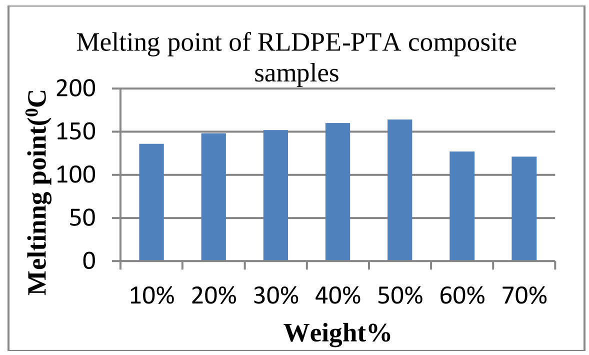

Figure 15b: Melting points of RLDPE-PTA composite sample

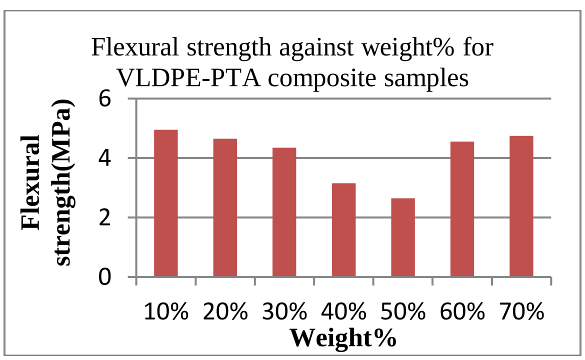

Fig14a: flexural strength of the VLDPE-PTA composite samples

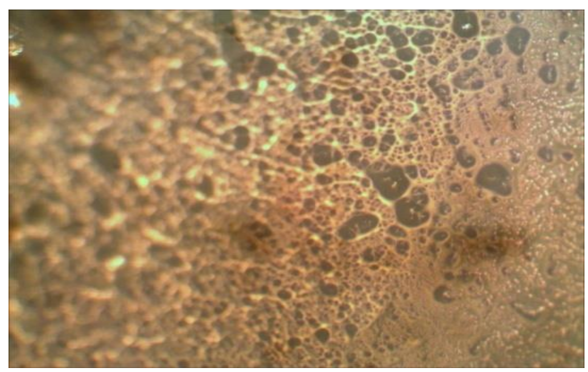

Fig16a: Microstructural view of 90% VLDPE-10%PTA

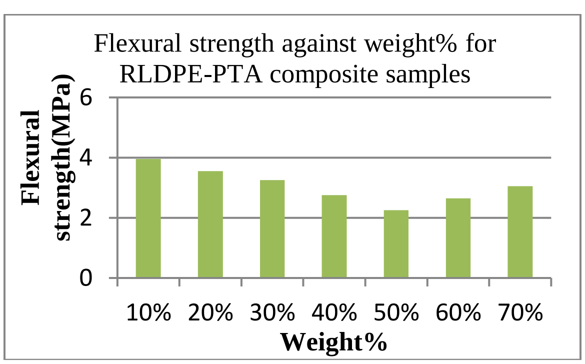

Fig14b: flexural strength of the RLDPE-PTA composite samples

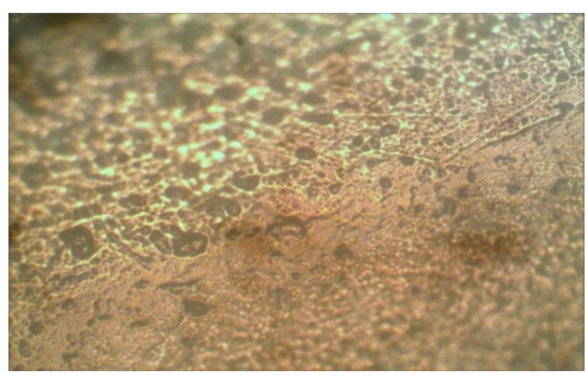

Fig 16b: Microstructural view of 90% RLDPE-10%PTA

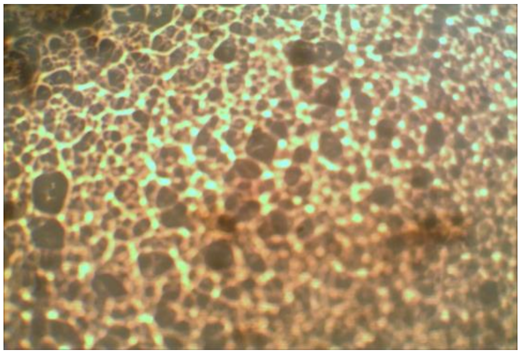

Fig17a: Microstructural view of 80% VLDPE-20%PTA

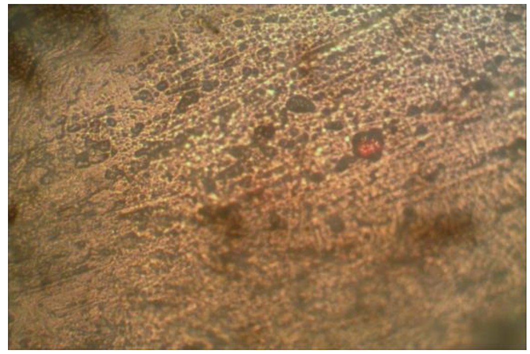

Fig19a: Microstructural view of 60% VLDPE- 40%PTA

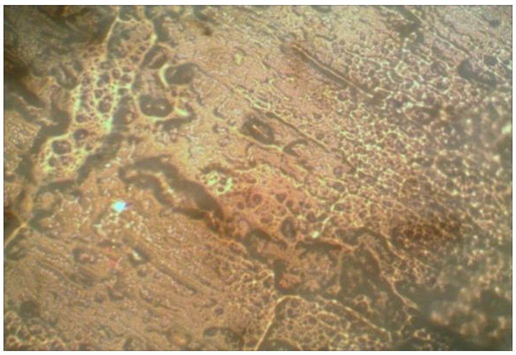

Fig17b: Microstructural view of 80% RLDPE-20%PTA

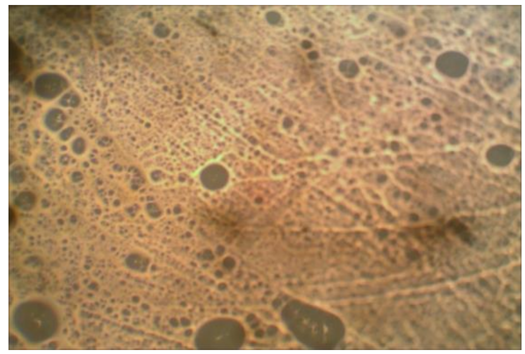

Fig 19b: Microstructural view of 60% RLDPE-40%PTA

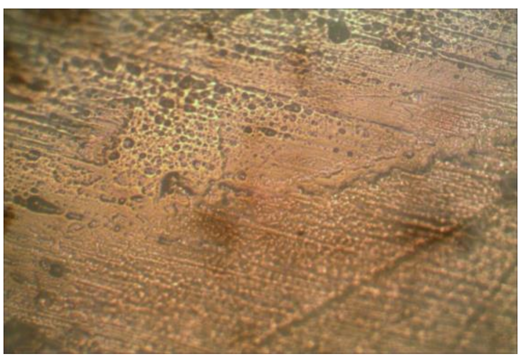

Fig 18a: Microstructural view of 70% VLDPE-30%PTA

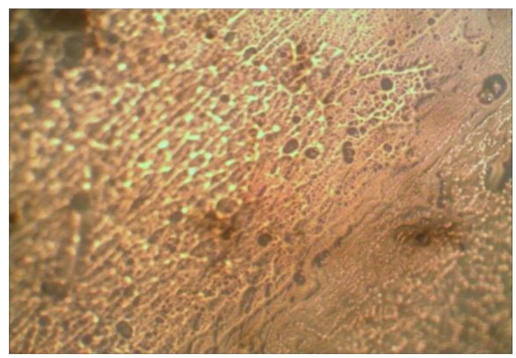

Fig 20a: Microstructural view of 50% VLDPE-50%PTA

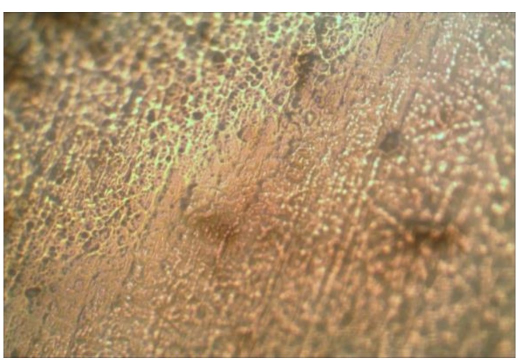

Fig 18b: Microstructural view of 70% RLDPE-30%PTA

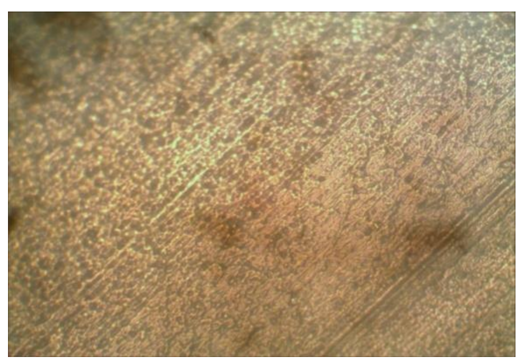

Fig 20b: Microstructural view of 50% RLDPE-50%PTA

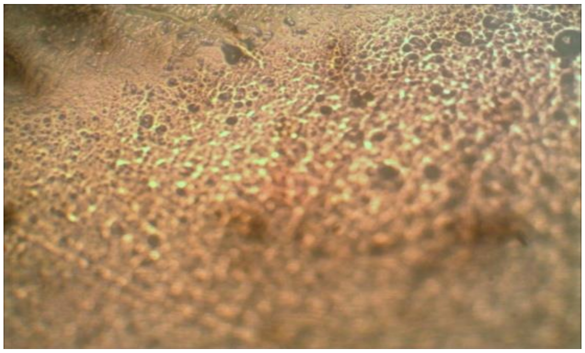

Fig 21a: Microstructural view of 40% VLDPE- 60% PTA

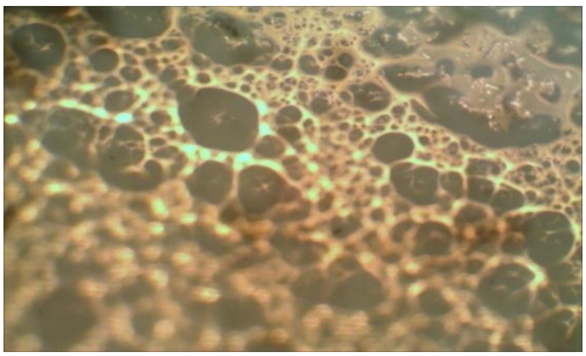

Fig 21 b: Microstructural view of 40% RLDPE- 60% PTA

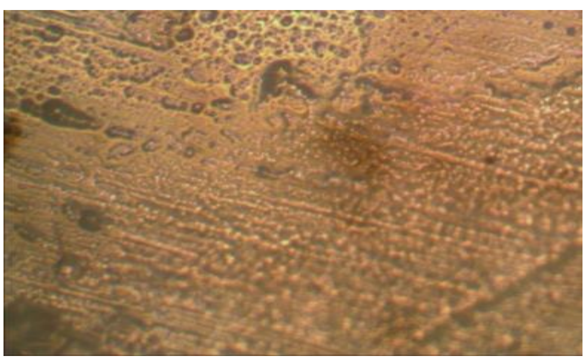

Fig 22a: Microstructural view of 30% VLDPE- 70% PTA

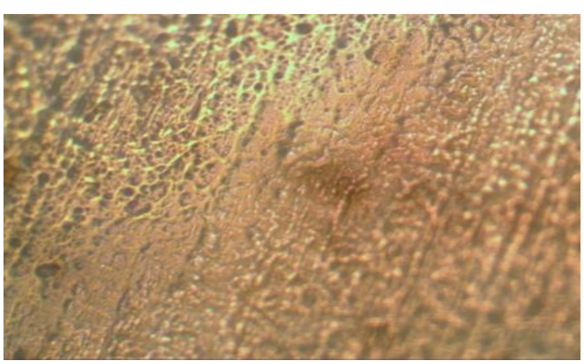

Fig 22b: Microstructural view of 30% RLDPE- 70% PTA

III. RESULTS AND DISCUSSION

The results obtained from the experiments conducted were presented in the figures below. The engineering properties of the VLDPE-PTA composites and RLDPE-PTA composites materials were determined and compared. The graphs of tensile stress versus tensile strain of the composites materials of virgin low-density polyethylene (VLDPE) and recycled low-density polyethylene (RLDPE) mixed with palm trunk ash were shown from figures 5 to 11. Figures 12a and 12b showed the ultimate tensile strengths of the two composites materials. The hardness, flexural strength, and melting point of composites materials of virgin low-density polyethylene and recycled low-density polyethylene mixed with palm trunk ash were shown in figures 13 to 15. The figures from 16 to 22 showed optical microstructural of the composites of 10 to 70% palm trunk ash on the virgin low-density polyethylene and Recycled low-density polyethylene.

DISCUSSION

The graphs of tensile stress versus tensile strain of the composites materials showed that the materials were slightly brittle. The brittleness was because the composites did not sustain large deformations before fracture, and some of the stress-strain diagrams had no yield point.

The ultimate tensile strengths of the composites with 40% and 50% volume of PTA were higher than the 10%, 20%, 30%, 60, and 70% PTA while the highest ultimate tensile strength of 14.4102 MPa was obtained for the VLDPE-PTA and 12.8955 MPa for the RLDPE-PTA at 50% volume of PTA. The results showed that tensile strength is 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 was highest at an equal amount of filler and PTA and decreased with an increasing filler or PTA content if the filler matrix adhesion was weak, and these accounts for the reason why the tensile strength of 10%, 20%, 30%, 60% and 70%volume fraction of PTA was lower than that of 40% and 50% PTA. However, the high tensile strength of the 40% and 50% PTA could be because there was moderate palm trunk ash in them. This may mean that at a particular volume of palm trunk, the tensile strength was increasing or decreasing. It might also be because there were strong interfacial adhesions between the palm trunk ash fillers and low-density polyethylene matrix or better stirring during the production process. The fluctuation of the graph was 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 polyethylene, it can be observed that the VLDPE-PTA composites have a higher tensile strength than the RLDPE-PTA composites. This could be because of the impurities that might have been incurred into the low-density polyethylene during recycling, thereby reducing the effective bond between the filler and the matrix.

The hardness value of the composites increases from 156 to 223 for virgin low-density polyethylene and 137 to202 for recycled low-density polyethylene with an increase in the palm percentage trunk ash to 50% and decreases on further addition as shown in figures 13a and 13b. The increase was due to the rigid nature of palm trunk ash at an equal amount with PTA. The hardness of the palm trunk ash would not allow quick penetration of the indenter on indentation. The graphs of hardness against the weight of recycled and virgin low-density polyethylene composite presented that VLDPE-PTA composites are more rigid than the RLDPE-PTA. This could be due to impurities that must have been introduced during the recycling in the form of gas or any other form. Nevertheless, since the Recycled low-density polyethylene is cheaper and reduces waste in the streets, it could be observed that at an equal amount of palm trunk ash, the hardness of the RLDPE-PTA composite was at the peak.

The bar chart of flexural strength versus percentage weight of palm trunk ash in figures 14a and 14b showed that flexural strength decreased from 3 95MPa to 2.25MPa for recycled low-density polyethylene as the percentage of palm trunk ash increased to 50% and decreased on further increment. Flexural strength is the ability of the 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 polyethylene matrix, distortion in the microstructure caused by the 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.

Figures 15a and 15b showed that the melting point graph against the weight of composites materials increases with an increase in the volume fraction of percentage to 50%PTA. This resulted from the addition of the palm trunk, thereby increasing the strength of the bonds.

The micro-optical structure of the composites of 10 to 70% palm trunk ash on the virgin low-density polyethylene and Recycled low-density polyethylene were compared. The crystalline structures, porosity, and atomic bonding of virgin low-density polyethylene were lowered than Recycled low-density polyethylene as viewed through a microscope.

IV. CONCLUSION AND RECOMMENDATION

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

Also, as compared between the tensile strength of RLDPE-PTA and VDPE-PTA, it was concluded that although the virgin material was more effective than the recycled material, the quality of the recycled composites was increased with an increase in the PTA at 50% but decreased besides of PTA.

The increase in palm trunk ash to 50% also increases the hardness of the composite. The increase in palm trunk ash to a level of 50% decreases the flexural strength of the composite. These imply that the 10% PTA composite has the highest flexural strength.

The graph of temperature to percentage weight can be seen that the melting point increases with an increase in palm trunk ash to 50% level and decreases in addition.

RECOMMENDATIONS

Finer particles such as nano-sized particles should be considered for recycled low-density polyethylene matrix systems at different filler contents. Other methods should be considered for the production of the composite, at filler contents lower than those used for this experiment (preferably at 5% weight increment), to see if the method of production of the composite would provide a better composite material as compared with the compression in molding method used for this experiment.

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

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

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